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SUMMARY OF RESEARCH 2001



**Department of Operations Research
Graduate School of Operational and Information Sciences**

**James D. Eagle
Chair**

**Kevin R. Wood
Associate Chair for Research**

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

RADM David R. Ellison, USN
Superintendent

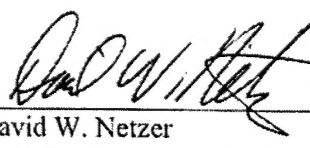
Richard Elster
Provost

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Reviewed by:


Danielle Kuska
Director, Research Administration

Released by:


David W. Netzer
Associate Provost and
Dean of Research

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THE NAVAL POSTGRADUATE SCHOOL MISSION

Increase the combat effectiveness of the U.S. and allied forces and enhance the security of the U.S.A. through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense related challenges of the future.



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PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Operations Research during 2001. The summary also contains thesis abstracts for those students advised by Operations Research faculty during 2001.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil/~code09/>

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts*: A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research*: A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research*: An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
<http://web.nps.navy.mil/~code09/publications.html>.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, and maintains the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- Reimbursable (Sponsored) Program: This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- Naval Postgraduate School Institutionally Funded Research (NIFR) Program: The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2001, the level of research effort overall at the Naval Postgraduate School was 148 faculty work years and exceeded \$48 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2001, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2001 is provided in Figure 1.

INTRODUCTION

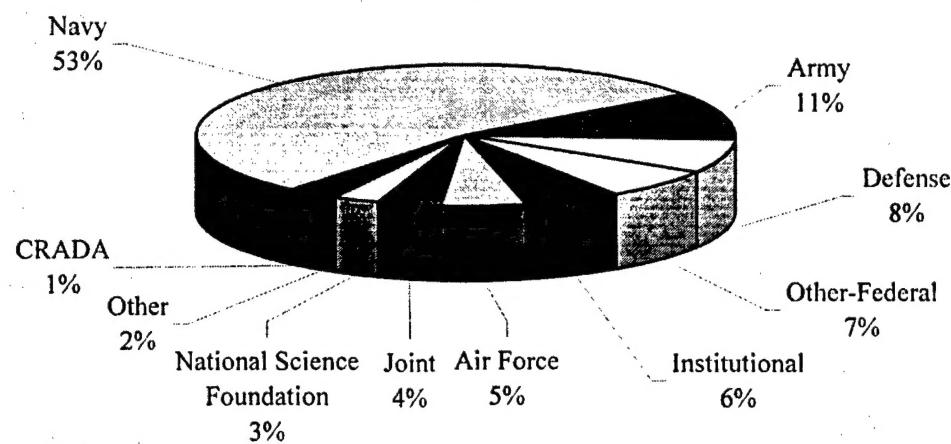


Figure 1. Profile of NPS Research and Sponsored Programs (\$52M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2001 is provided in Figure 2.

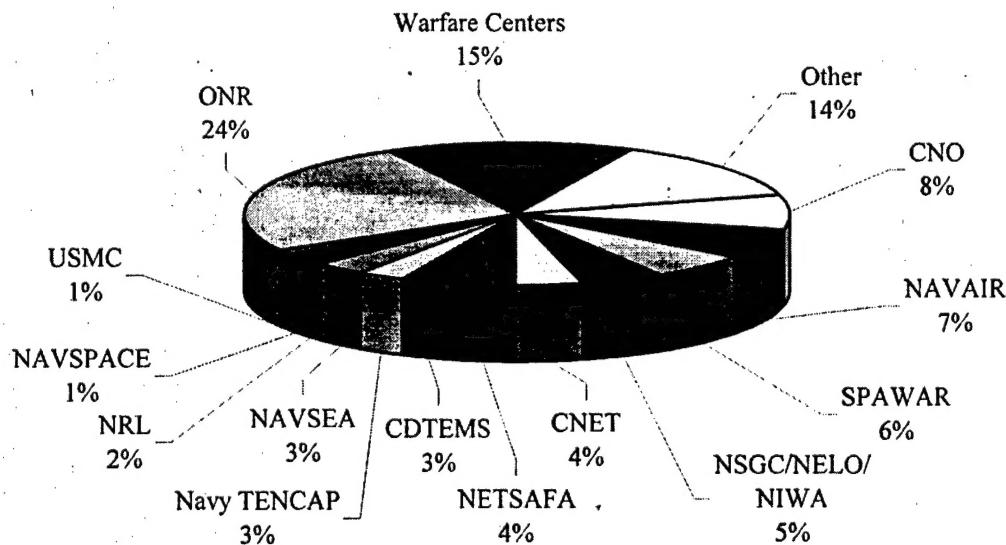


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs (\$29M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

September 2002

**DEPARTMENT OF
OPERATIONS RESEARCH**

**JAMES D. EAGLE
CHAIR**

DEPARTMENT SUMMARY

OVERVIEW:

The Naval Postgraduate School Operations Research (OR) program is a world-class curriculum designed to teach students the science of helping people and organizations make better decisions.

This science is necessary in today's increasingly complex operating environment in which officers and managers must respond quickly to a vast array of demands while also weighing the options and consequences of each into his or her final decision. OR offers a scientific approach through the use of many tools and techniques in order to assist an individual in his or her decision making process.

The military specifically uses OR at the strategic, operational, and tactical levels. OR applications cover the gamut of military activities including: National policy analysis, resource allocation, force composition and modernization, logistics, human resources, battle planning, flight operations scheduling, intelligence, command and control, weapon selection, engagement tactics, maintenance and replenishment, and search and rescue.

The Department of Operations Research mission is:

- To educate analysts who are fully capable of conducting independent analytical studies of military problems, and have an educational basis for continued learning and development.
- To provide the United States government and our allies with military officers who have a comprehensive knowledge of military operations research, and who can perform and manage quantitative analysis of operational and other Defense problems.
- To provide operations research and general analysis support to DoD.
- To develop and maintain a world-class research program in operations research and related areas.

CURRICULA SERVED:

- Modeling, Virtual Environments and Simulation (MOVES)
- Electronic Warfare Systems International
- Information Systems and Operations
- Information Systems Technology
- Information Warfare
- Joint C4I
- Intelligence Information Management
- Naval/Mechanical Engineering
- Operations Analysis
- Operational Logistics
- Advanced Science (Applied Math)
- Product Development 21
- Space Systems Operations International
- Space Systems Operations
- Systems Engineering/Integration
- Manpower Systems Analysis
- Undersea Warfare
- Undersea Warfare International

DEGREES GRANTED:

- Master of Science in Operations Research
- Master of Science in Applied Science
- Doctor of Philosophy

DEPARTMENT SUMMARY

RESEARCH THRUSTS:

- Probability and Stochastic Processes
- Optimization
- Statistics and Data Analysis
- Human Factors and Systems Integration
- Simulation and War Gaming
- Search, Detection and Evasion

RESEARCH CHAIRS:

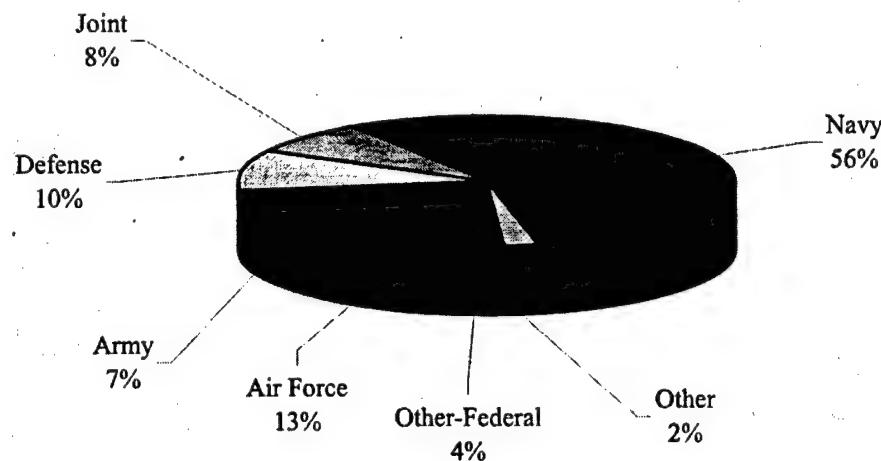
- Chair for Manpower Modeling
- Chair of Applied Systems Analysis
- Chair of Tactical Analysis

RESEARCH FACILITIES:

- Secure Computing and Simulation Lab (WARLAB)
- Optimization Lab
- Human Systems Integration Laboratory (HISL)

RESEARCH PROGRAM (Research and Academic)-FY2001:

The Naval Postgraduate School's sponsored program exceeded \$49 million in FY2001. Sponsored programs include both research and educational activities funded from an external source. A profile of the sponsored program for the Department of Operations Research is provided below.



Size of Program: \$2290K

FACULTY LISTING

Eagle, James D.
Professor and
Chair
OR/Er
656-2654
jeagle@nps.navy.mil

Wood, R. Kevin
Professor and
Associate Chair for Research
OR/Wd
656-2523
kwood@nps.navy.mil

Anderson, Timothy, LCDR, USN
Military Instructor
OR/At
656-3583
tpanderson@nps.navy.mil

Gaver, Donald P., Jr.
Distinguished Professor
OR/Gv
656-2605
dgaver@nps.navy.mil

Lucas, Thomas W.
Associate Professor
OR/Lt
656-3039
twlucas@nps.navy.mil

Boensel, Matthew G., CDR, USN
Military Instructor
OR/Bm
656-3489
mgbboense@nps.navy.mil

Hoivik, Thomas H.
Senior Lecturer
OR/Ho
656-2040
thhoivik@nps.navy.mil

Maher, Kevin J., CDR, USN
Military Instructor
OR/Mk
656-2691
kjmaher@nps.navy.mil

Bradley, Gordon H.
Distinguished Professor
OR/Bz
656-2359
gbradley@nps.navy.mil

Jacobs, Patricia A.
Professor
OR/Jc
656-2258
pajacobs@nps.navy.mil

Miller, Nita
Visiting Assistant Professor
OR/Mn
656-2281
nlmiller@nps.navy.mil

Brown, Gerald G.
Distinguished Professor
OR/Bw
656-2140
gbrown@nps.navy.mil

Kemple, William G.
Associate Professor
OR/Ke
656-3309
kemple@nps.navy.mil

Parker, Joel R., LTC, USA
Military Instructor
OR/Jp
656-2636
tpanderson@nps.navy.mil

Buss, Arnie
Assistant Professor
OR/Bu
656-3259
abuss@nps.navy.mil

Koyak, Robert A.
Assistant Professor
OR/Kr
656-2688
rakoyak@nps.navy.mil

Paulo, Eugene P., LTC, USA
Military Instructor
OR/O1
656-3452
eppaulo@nps.navy.mil

Buttrey, Samuel E.
Assistant Professor
OR/Sb
656-3035
buttrey@nps.navy.mil

Kress, Moshe
Visiting Professor
OR/Ko
656-3647
mkress@nps.navy.mil

Read, Robert R.
Professor
OR/Re
656-2382
rread@nps.navy.mil

Dell, Robert
Associate Professor
OR/De
656-2853
dell@nps.navy.mil

Lawphongpanich, Siriphong
Associate Professor
OR/Lp
656-2106
slawphon@nps.navy.mil

Rosenthal, Richard E.
Professor
OR/R1
656-2795
rosenthal@nps.navy.mil

FACULTY LISTING

Rowe, Anton Research Assistant Professor OR/Ar 656-2385 arowe@nps.navy.mil	Schrady, David A. Distinguished Professor OR/So 656-2801 dschrady@nps.navy.mil	Widdis, Daniel B., LCDR, USN Military Instructor OR/Wi 656-3040 dbwiddis@nps.navy.mil
Salmeron, Javier Research Assistant Professor OR/Sa 656-2779 jsalmero@nps.navy.mil	Taylor, James G. Professor OR/Tw 656-2683 jtaylor@nps.navy.mil	Williams, Laura M. Research Assistant Professor OR 656-4140 lmwilliams@nps.navy.mil
Sanchez, Paul Visiting Assistant Professor OR/Sp 656-3053 pisanche@nps.navy.mil	Washburn, Alan R. Professor OR/Ws 656-3127 awashburn@nps.navy.mil	
Sanchez, Susan M. Professor OR/Su 656-2780 smsanche@nps.navy.mil	Whitaker, Lyn R. Associate Professor OR/Wh 656-3482 lwhitaker@nps.navy.mil	

PROJECT SUMMARIES

CHAIR OF APPLIED SYSTEMS ANALYSIS

CDR Matthew G. Boensel, USN

Department of Operations Research

Sponsor: Chief of Naval Operations-Assessment Division (N81)

OBJECTIVE: In accordance with the current Memorandum of Understanding between the Superintendent, Naval Postgraduate School and N81 (dated 12 April 1993), funds will provide research support for analysis of issues of interest to the Navy. Research will provide professional development of NPS faculty and students.

SUMMARY: Specific elements of this project include:

- Support for student thesis tours, in association with the OA program office.
- Support for faculty development in applied systems analysis and faculty travel to DC in support of N81 activities.
- Support for student and faculty travel for thesis research projects.

Of note, a special short course refresher on Operations Research methods was developed and delivered for action officers in the Assessment Division (N81).

PRESENTATIONS:

Washburn, A., "Introduction to Military Operations Research," Pentagon, Arlington, VA, 21-25 May 2001.

THESIS DIRECTED:

Borden, K., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREA: Other (Operations Research)

KEYWORDS: Optimization, Operations Research, Combat Logistics

AN ARCHITECTURE FOR DYNAMIC PLANNING SYSTEMS USING LOOSELY COUPLED COMPONENTS

Gordon H. Bradley, Professor

Arnold H. Buss, Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Design and develop an architecture for dynamic map-based military planning applications using new platform-independent software technology. This is a continuing research project.

SUMMARY: The research has designed and developed a "loosely coupled components" architecture that has been demonstrated by constructing a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding addition components.

PRESENTATIONS:

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

PROJECT SUMMARIES

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

THESES DIRECTED:

Fricke, C., "Operational Logistics Wargame," Masters Thesis, Naval Postgraduate School, December 2001.

San Jose, A., "Analysis, Design, Implementation and Evaluation of Graphical Design Tool to Develop Discrete Event Simulation Models Using Event Graphs and Simkit," Masters Thesis, Naval Postgraduate School, September 2001.

Lenhardt, T., "Evaluation of Combat Service Support Logistics Concepts for Supplying a USMC Regimental Task Force," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Project Monterey: A system to support real-time and near real-time military decision-making using network models based on the Loosely Coupled Components Architecture (LCCA).

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

LARGE-SCALE OPTIMIZATION

Gordon H. Bradley, Professor

Gerald G. Brown, Distinguished Professor

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models, and develop graph and network algorithms for dynamic map-based military planning. This is a continuing research project.

SUMMARY: One part of this research developed a new algorithm called BEST (Bound, Enumerate, Sample and Test) for solving two-stage stochastic integer programs. The algorithm has been applied to network-interdiction problems with uncertain interdiction success. Another part of this research designed and developed a toolkit of methods to quickly construct graph and network algorithms. The algorithms were integrated into a dynamic map-based military planning system that operates over heterogeneous computer networks. The system can download algorithms over a computer network and execute them to analyze operations. The design allows algorithms to be easily added to the planning system.

PUBLICATIONS:

Brown, G., Keegan, J., Vigus, B. and Wood, K., "The Kellogg Company Optimizes Production, Inventory and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Israeli, E. and Wood, K., "Shortest-Path Network Interdiction," in review.

PROJECT SUMMARIES

PRESENTATIONS:

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

Brown, G., "Fast Theater Attack Model," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G., Byrne, P. and Washburn, A., "Fast Theater Model (FATHM)," 69th Military Operations Research Society Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Dell, R.F., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Newman, A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Morton, D., Salmeron, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programs," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Morton, D., Salmeron, J. and Wood, R.K., "A Stochastic Program for Optimizing Military Sealift Subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Sanchez, S. and Wood, K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate Then Screen Method," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Mathematics Department Seminar, University of California at Davis, Davis, CA, 5 October 2001.

Wood, K., "Network Interdiction," Sandia National Laboratories, Albuquerque, NM, 2 July 2001.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

Borden, K.D., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

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Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Dynamic Planning

FAST THEATER MODEL

Gerald G. Brown, Distinguished Professor

Alan Washburn, Professor

Department of Operations Research

Sponsors: Joint Staff (J8) and the Naval Postgraduate School

OBJECTIVE: Provide support to the Joint Chiefs of Staff in improving FATHM, the FAst THeater Model.

SUMMARY: FATHM is an aggregated combat model that is part optimization and part simulation, a hybrid model. Air-to-ground activity is optimized, while ground-to-ground activity is simulated using a Lanchester model that imitates COSAGE, a high-resolution simulation. Progress in FY2001 includes

- a mechanism for target valuation
- based on target valuation, a mechanism for calculating force ratios and FEBA movement
- direct calls to an LP solver, a more efficient method than indirect calls via GAMS
- an improved method for calculating Lanchester coefficients based on the COSAGE killer-victim scoreboard
- improved input and output procedures

PUBLICATIONS:

Washburn, A., *The Fast Theater Model (FATHM)*, Naval Postgraduate School Technical Report, NPS-OR-01-002-PR, 2001.

PRESENTATIONS:

Brown, G., Byrne, P. and Washburn, A., "The Fast Theater Model," 69th Military Operation's Research Society Symposium, 12-14 June 2001.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Optimization, Weapon Allocation

LARGE-SCALE OPTIMIZATION

Gerald G. Brown, Distinguished Professor

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and mathematical programs. Develop extensions of network-interdiction techniques to solve more general system interdiction models.

SUMMARY: Have completed and delivered to JCS/J8 and U.S. Army Center for Army Analysis, Ft. Belvoir, Virginia, the Fast Theater Model (FATHM), an integrated air-to-ground attack model (using large-

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scale optimization) and ground-to-ground model (using Lanchester equations). FATHM runs full-scale theater wars in less than five minutes with all the fidelity expected by Air Force and Army planners. The goal is to distribute targets among our forces optimally, and also to gauge the weapons and platform requirements to win. In other research areas, a Lagrangian-relaxation technique has been developed for quickly solving certain network-interdiction problems, and have an extension of integer cutting planes for solving integer programs has been devised. Unlike standard cuts, the "super-valid inequalities" can cut away valid integer solutions, but they are guaranteed to not cut away useful solutions.

PUBLICATIONS:

Brown, G., Keegan, J., Vigus, B. and Wood, K., "The Kellogg Company Optimizes Production, Inventory and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Israeli, E. and Wood, K., "Shortest-Path Network Interdiction," in review.

PRESENTATIONS:

Brown, G.G., "Fast Theater Attack Model," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G.G., Byrne, P. and Washburn, A., "Fast Theater Model (FATHM)," 69th Military Operations Research Society Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Dell, R.F., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G. and Newman, A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Morton, D., Salmeron, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programs," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Morton, D., Salmeron, J. and Wood, R.K., "A Stochastic Program for Optimizing Military Sealift Subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Sanchez, S. and Wood, K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate Then Screen Method," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Mathematics Department Seminar, University of California at Davis, Davis, CA, 5 October 2001.

Wood, K., "Network Interdiction," Sandia National Laboratories, Albuquerque, NM, 2 July 2001.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

Borden, K.D., "Optimizing the Number and Employment of Combat Logistics Force Shuttle Ships, with a Case Study of the New T-AKE Ship," Masters Thesis, Naval Postgraduate School, September 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

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Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning, and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Other (Optimization, Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Network Interdiction

OPTIMIZING NAVY PROGRAM PLANNING

Gerald G. Brown, Distinguished Professor

Robert F. Dell, Associate Professor

Anton Rowe, Research Associate

Javier Salmeron, Research Assistant Professor

Department of Operations Research

Sponsor: Chief of Naval Operations (N81)

OBJECTIVE: To provide N81 with a desktop, optimization-based decision-support tool to integrate, rationalize, and schedule the way in which and the rate at which Navy capital spending programs should be conducted over the next 25 years.

SUMMARY: A prototype custom-built optimization-based decision-support system was delivered complete with graphical user interface and custom heuristic. The decision-support system prescribes complete scenarios that can follow all Navy guidelines, including details such as keeping shipyards efficiently employed, constraining aircraft average age, and meeting IWARS (Integrated Warfare Architecture) requirements. Without the system, complete scenarios must be manually assembled, which is a laborious, error-prone task. Efforts continue to improve the system.

PRESENTATIONS:

Dell, R.F. and Brown, G.G., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESIS DIRECTED:

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

OTHER:

Software: The following versions of the decision support system were delivered to N81.

Version	Delivered	Comments	Documentation
P.01.01	02/28/01	Prototype Interface. Heuristic Solver	No
P.03.03	06/04/01	Prototype Interface. Heuristic Solver	No
P.07.04	11/13/01	Prototype/semi-operative Interface. Heuristic Solver	Yes

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting

PROJECT SUMMARIES

OPTIMIZING TOMAHAWK LAND ATTACK PREDESIGNATION

Gerald G. Brown, Distinguished Professor

Department of Operations Research

Alexandra M. Newman, Assistant Professor

Colorado School of Mines

Richard E. Rosenthal, Professor

Department of Operations Research

Sponsors: Naval Surface Warfare Center - Dahlgren Division

and Office of Naval Research

OBJECTIVE: Testing and refining a heuristic procedure to efficiently assign tasks requiring Tomahawk Land-Attack Missiles (TLAMs) to the firing platforms of a battle group, i.e., surface ships and submarines.

SUMMARY: A fast heuristic was developed to assign Tomahawk missiles to firing platforms. Solutions obtained with this heuristic were compared against those obtained manually by the Tomahawk Strike Coordinator, i.e., using current practice. The heuristic solutions are of better quality than the manual ones and can be obtained much more quickly than with any manual process. Additionally, the heuristic was enhanced to incorporate these operational features: (i) The ability to plan subsequent tasking before the execution of the current tasking; (ii) the ability to manually allocate tasks to firing platforms with the guidance of the heuristic; and (iii) a function for identifying why certain tasks might not be able to be assigned to firing platforms, and for suggesting task-list modifications that would make it possible to accommodate those tasks.

PUBLICATIONS:

Brown, G.G., Newman, A.M., Rosenthal, R.E. and Rowe, A.A., *Optimizing Tomahawk Strikes*, Naval Postgraduate School Technical Report, NPS-OR-01-001-PR, January 2001, (also appeared in *Naval Postgraduate School Research Newsletter*).

PRESENTATIONS:

Brown, G.G., Newman, A.M., Rosenthal, R.E. and Rowe, A.A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESES:

Kubu, J.A., "Enhancing Real-time Tomahawk Predesignation to Diagnose Conflicts, Prescribe Improvements, and Plan Multiple Strikes," Masters Thesis, Naval Postgraduate School, September 2001.

Wingeart, P.H., "An Improved Heuristic for Tomahawk Land-Attack Predesignation, Enhanced to Accommodate Manual Planning, and Validated with Fleet Exercise Data," Masters Thesis, Naval Postgraduate School, September 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Surface/Under Surface Vehicles, Ships and Watercraft

KEYWORDS: Missiles, Missile Selection, Naval Operations, Tomahawk Land Attack Missile

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MARITIME OPERATIONS SIMULATION AND APPLICABILITY ASSESSMENT FOR DEEPWATER

**Arnie Buss, Assistant Professor
Department of Operations Research
Sponsor: United States Coast Guard**

OBJECTIVE: Determine if contractor-supplied software tools will meet the Coast Guard's needs for modeling deepwater acquisition.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Deepwater Acquisition, Simulation, Validation

ANALYSIS IN SUPPORT OF USMC PME SURVEY

**Samuel E. Buttrey, Assistant Professor
Lyn R. Whitaker, Associate Professor
Department of Operations Research
Sponsor: Marine Corps Combat Development Command**

OBJECTIVE: To provide support to the Studies and Analysis Division (S&A), Marine Corps Combat Development Command for completion of the Marine Corps Professional Military Education (PME) Study. Specifically, to provide assistance with survey question development, survey data analysis, and to be the principal performers of data mining and analysis of existing Marine Corps databases in order to complete Tasks 2-4 in the PME Study Directive.

SUMMARY: This research project was a short fuse project with very specific deliverables. The primary purpose of NPS involvement was to provide S&A with any statistical support needed in their study of PME for the Marine Corps University. All deadlines and deliverables were met. These included help with constructing and on-line survey administered to all USMC officers. This survey captured views of officers about their PME experiences and their views of the importance and impact on USMC of resident and nonresident PME. Extensive summary statistics, corresponding graphics and interpretation of the results of this survey were delivered to S&A. These were incorporated into the final report. In addition, the Center for Naval Analysis data base, the USMC officer "Street to Fleet" data was scrutinized to see if there was any relationship between PME history and success as measured by promotion to various ranks and length of retention. The results of this analysis, including descriptive statistics and model fits to account for other variables influencing success, were delivered to S&A in the form of an interim report. These results were also used in the final report. Because the primary role of NPS was support for S&A's study, the results of NPS's contributions are integrated into S&A's report: "Professional Military Education Study for Marine Corps University: Final Report" (2001).

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Professional Military Education (PME), Manpower, Education

ANALYSIS OF PRE SOURCE INFORMATION

**Samuel E. Buttrey, Assistant Professor
Department of Operations Research
Sponsor: Personnel Security Research Center**

OBJECTIVE: To provide support to PERSEREC in analyzing the quality of information provided to their investigators by different sources with regard to different security considerations.

SUMMARY: This research project supported PERSEREC in measuring the quality of the information provided by different sources in their investigation of personnel receiving security clearances. Particular

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attention was paid to the problem of inter-rater reliability (gauging the extent to which different investigators reach the same conclusions when presented with the same report), or IRR. The results of this analysis, including descriptive statistics, test of hypothesis, and measures of IRR were delivered to PERSEREC for inclusion in that organization's final report.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Manpower, Security Clearance, Inter-rater Reliability

OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT

Robert F. Dell, Associate Professor

Department of Operations Research

Sponsor: U.S. Army, Assistant Chief of Staff for Installation Management

OBJECTIVE: Develop optimization models to assist with installation management.

SUMMARY: The investigator is providing research, support, and development of optimization models to assist the Army's Assistant Chief of Staff for Installation Management. The integer-linear programs OSAF (Optimal Stationing of Army Forces) and BAEC (Budget Allocation for Environmental Cleanup) were the primary 2001 development effort. The Center for Army Analysis used OSAF for numerous stationing studies and to help answer a QDR (Quadrennial Defense Review) issue: "What are the infrastructure requirements to support the Army of the future?" The Army's Base Realignment and Closure Office used BAEC to help plan \$414 million in environmental cleanup at 334 sites on 54 current and former Army installations.

PUBLICATIONS:

Connor, G., Dell, R.F. and Tarantino, W.J., "An Integer Linear Program to Recommend Stationing of Army Forces," 27 November 2001. (Draft paper selected as a Finalist for 2001 Military Operations Research Richard H. Barchi Prize.)

PRESENTATIONS:

Tarantino, W.J., Dell, R.F. and Connor, G., "Optimal Stationing of Army Forces (OSAF)," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Tarantino, W.J., "Optimal Stationing of Army Forces," National Meeting of the Institute for Operations Research and the Management Sciences, Miami Beach, FL, 4-7 November 2001.

THESES DIRECTED:

Ardic, S., "Funding Site Cleanup at Closing Army Installations: A Stochastic Optimization Approach," Masters Thesis, Naval Postgraduate School, December 2001.

Gezer, M., "Optimal Stationing of the United States Army Forces in Korea," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Optimization)

KEYWORDS: BRAC, Capital Budgeting, Optimization, Mixed Linear Integer Programming Application

PROJECT SUMMARIES

PLANNING CAPITAL INVESTMENTS USING OPTIMIZATION

Robert F. Dell, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Conduct research in optimal planning of capital investments with two short-term subjects, (a) the Capital Investment Planning Aide (CIPA) for U.S. Navy Force Structure planning and (b) the Japan Petroleum Distribution model (JPDM) for U.S. Navy infrastructure planning.

SUMMARY: This effort to conduct research on theory and algorithms for solving real-world capital budgeting problems with prescriptive optimization had two short-term goals. The first was to enhance the Capital Investment Planning Aide (CIPA) for U.S. Navy Force Structure planning. We have formulated an optimization model of the Navy's spending plans for major weapons systems (e.g., ships and aircraft) and demonstrated it with current planning data. The second short-term goal was to enhance the Japan Petroleum Distribution model (JPDM) for U.S. Navy infrastructure planning. Several new models were developed.

PRESENTATIONS:

Dell, R.F. and Brown, G.G, "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Noble, J.D., "Scheduling and Distributing Intra-Theatre Wartime POL Requirements," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

THESES DIRECTED:

Devlin, D.L., "Scheduling and Distributing Intra-Theater Wartime POL Requirements Under Uncertainty," Masters Thesis, Naval Postgraduate School, December 2001.

Garcia, R.M., "Optimized Procurement and Retirement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2001.

Harmon, J.V., "Planning U.S. Pacific Command Wartime Fuel Distribution," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Software: The following versions of CIPA were delivered to N81.

Version	Delivered	Comments	Documentation
P.01.01	02/28/01	Prototype Interface. Heuristic Solver	No
P.03.03	06/04/01	Prototype Interface. Heuristic Solver	No
P.07.04	11/13/01	Prototype/semi-operative Interface. Heuristic Solver	Yes

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting, Other (Optimization and Decision Support)

PROJECT SUMMARIES

OPTIMIZING THE FLOW OF MARINE RECRUITS THROUGH ENTRY-LEVEL TRAINING

Robert F. Dell, Associate Professor
Javier Salmeron, Research Assistant Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: Assist the Marine Corps in developing an optimization model to prescribe a flow of enlisted recruits through entry-level training.

SUMMARY: The Marine Corps viewed the total time non-infantry enlisted wait for MOS training as unacceptably high. Integer linear programs were developed that model the flow of enlisted recruits through entry-level training. The models' recommendations highlight how more coordinated actions by recruiting planners and military occupational schools can significantly reduce the total Marine-year wait time. Tests carried out employing recent data show reductions of more than 50 percent.

THESIS DIRECTED:

Whaley, D.L., "Scheduling the Recruiting and MOS Training of Enlisted Marines," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Manpower, Personnel and Training, Modeling and Simulation, Other (Optimization)

KEYWORDS: Integer Optimization, Scheduling, Resource Constrained Problems

NAVY AIRLIFT

William Gates, Associate Professor
Graduate School of Business and Public Policy
Alan Washburn, Professor
Department of Operations Research
Sponsor: Chief of Naval Operations (N78)

OBJECTIVE: The Navy operates a fleet of operational support aircraft (OSA) that have the function of moving high priority passengers and cargo in wartime. The fleet is aging, and must gradually be replaced with more modern aircraft. The objective is first to measure the wartime demand for OSA transport in the event of a major war, and then to design a fleet that satisfies that demand at minimal cost.

SUMMARY: The basic approach is to estimate wartime demand for OSA transport, and then design a fleet that can meet that demand efficiently, bearing in mind that the costs of current OSA aircraft are "sunk." A fleet management tool OSAMIX is developed as an Excel workbook. Peacetime demand is estimated by recovering appropriate records from the JALIS database system, and then inflated to prospective wartime demand by applying a "surge factor." Given the characteristics of various aircraft, OSAMIX then finds the fleet that minimizes the present value of the costs of meeting that demand. One conclusion is that it is cost-effective for the Navy to retire its fleet of C-12 turboprop aircraft in favor of a similarly scaled jet aircraft.

PUBLICATIONS:

Gates, W. and Washburn, A., *The Navy Operational Support Aircraft Fleet*, Naval Postgraduate School Technical Report, NPS-OR-01-006-PR, 2001.

THESIS DIRECTED:

Law, J., "Assessing the Performance and Cost of Logistics Airfleet Options," Masters Thesis, Naval Postgraduate School, December 2001.

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DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: OSA, Operational Support Aircraft, Cost-Effective

ANALYTICAL DECISION-SUPPORTING RESEARCH USING SYNTHESIZED ADAPTIVE-AGENT-BASED MODELING AND MATHEMATICAL MODELING

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsor: The Modeling, Virtual Environments and Simulation (MOVES) Institute

OBJECTIVE: Purpose of the research is to formulate and study models for the adaptive scheduling of time critical tasks under imperfect information in joint warfare with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts. The purpose of the modeling and analysis is to explore the advantages of using Genetic Algorithms in the adaptive scheduling of processing of time-critical tasks, with imperfectly known identity and arriving in random streams of "unknown," i.e., changing, properties. This is a generalization of the General Assignment Problem (GAP) treated (under assumptions of certainty) by mathematical programming. The models here are called the Generalized Generalized Assignment Problem (GGAP).

SUMMARY: Models for allocation of service to time-critical tasks with uncertain outcomes have been formulated.

PUBLICATIONS:

Glazebrook, K.D., Gaver, D.P. and Jacobs P.A., *On a Military Scheduling Problem*, Naval Postgraduate School Technical Report, NPS-OR-01-010, August 2001.

PRESENTATIONS:

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," XXI International Seminar on Stability Problems for Stochastic Models, Eger, Hungary, 28 January-3 February 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," MIT Lincoln Laboratory, 16 July 2001.

Gaver, D.P., Jacobs, P.A. and Pilnick, S.E., "Hybrid Approaches to Agent-Based Complex Adaptive Systems," MOVES Open House, 30 August 2001.

Gaver, D.P., Jacobs, P.A. and Pilnick, S.E., "Some Thesis Research Topics in Stochastic/Probabilistic OR," Presentation to MV4900, 6 December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: General Assignment Program, Generic Algorithms, Generalized Generalized Assignment Problem, GAP, GGAP

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JOINT EXPERIMENTATION HIGH-LEVEL LOW-RESOLUTION MODELING

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Steven E. Pilnick, Senior Lecturer

Wayne E. Meyer Institute of Systems Engineering

Sponsor: U.S. Joint Forces Command and the Naval Postgraduate School

OBJECTIVE: Purpose of the research is to formulate and study state space models for information operations in joint warfare with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts

SUMMARY: High-level-low-resolution models for the study of the Common Relevant Operational Picture (CROP) have been formulated, studied and used to provide insight on the benefits of the CROP.

PUBLICATIONS:

Gaver, D.P. and Jacobs, P.A., "A Model for Analyzing Blue Force Response to Region Invasion by Multi-Type Red Forces," forthcoming.

Barkdoll, T.C., Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Posadas, S., "Suppression of Enemy Air Defenses (SEAD) as an Information Duel," to appear in *Naval Research Logistics*.

DoD KEY TECHNOLOGY AREAS: Human-System Interface, Modeling and Simulation

KEYWORDS: Combat Models, Bayesian Perception Updating, Decision Analysis

MODELS FOR LIVER INSULT AND RECOVERY

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsor: Naval Health Research Center Detachment – Toxicology

OBJECTIVE: Use mathematical computer-based modeling and statistical methods to quantify the effects of a toxin on the liver.

SUMMARY: Mechanistic models for the effect of a toxic substance on the liver have been developed and experimental data have been analyzed.

CONFERENCE PRESENTATIONS:

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," Poster Session, 40th Annual Meeting, Society of Toxicology, San Francisco, CA, 24–29 March 2001.

OTHER:

Carpenter, R.L., Gaver, D.P., Jacobs, P.A., Narayanan, T.K., Jung, A. and Bobb, A., "A Mechanistic Mathematical Models of Cell Toxicity from APAP," forthcoming.

Carpenter, R.L., Gaver, D.P., Jacobs, P.A., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," forthcoming.

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Bobb, A., Carpenter, R.L., Gaver, D.P. and Jacobs, P.A., "High Dosage Model for the Effect of APAP on Liver Cells," forthcoming.

DoD KEY TECHNOLOGY AREAS: Biomedical, Human Systems Interface, Environmental Quality

KEYWORDS: PBPK/PD Compartment Modeling, Predictive Toxicology

TRAINING AND RESEARCH SUPPORT FOR DIRECTOR, OPERATIONAL TEST AND EVALUATION

Donald P. Gaver, Distinguished Professor

Patricia A. Jacobs, Professor

Department of Operations Research

Sponsors: Director, Operational Test and Evaluation, U.S. Army Analysis Command,
U.S. Army Training Analysis Command-Monterey and Naval Postgraduate School

OBJECTIVE: Purpose of the research is to develop training and reference material on a Web site and new methodology for operational testing which emphasizes modeling and simulation.

SUMMARY: Models for sequential stage system reliability growth via failure model removal have been formulated and studied. Models to assess the operational suitability of a platoon of advanced amphibious assault vehicles (AAAVs) have been formulated and studied. Materials for an operational test and evaluation Web site have been developed.

PUBLICATIONS:

Gaver, D.P., Jacobs, P.A. and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," *Safety & Reliability: ESREL 2001 Towards a Safer World*, Zio, E., Demichela, M., Piccinini, N., (eds.), Politecnico di Torino, Vol. 2, pp. 1109-1116, 2001.

Gaver, D.P., Jacobs, P.A. and Kemp, J., *Modeling the Operation of a Platoon of Amphibious Vehicles for Support of Operational Test and Evaluation (OT&E)*, Naval Postgraduate School Technical Report, NPS-OR-01-009, July 2001.

Gaver, D.P., Jacobs, P.A. and Seglie, E., *Stochastic Models for Promoting and Testing System Reliability Evolution*, Naval Postgraduate School Technical Report, NPS-OR-01-011, September 2001.

PRESENTATIONS:

Gaver, D.P., Jacobs, P.A and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," European Safety and Reliability Conference, Turino, Italy, 16-20 September 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, University of California at Davis, 22 February 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, Oregon State University, 26 February 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, Birmingham University, 28 September 2001.

Gaver, D.P. and Jacobs, P.A., "Dynamic Reliability," Seminar at the Department of Statistics, University of Oslo, 5 October 2001.

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THESES DIRECTED:

Lintz, G., "Analysis of Reliability and Life Data for AN/ASS-44(V) Forward Looking Infrared System to Forecast H-60 Operational Availability," Masters Thesis, Naval Postgraduate School, September 2001.

Kemp, J., "Modeling and Simulation in Support of Operational Test and Evaluation for the Advanced Amphibious Assault Vehicle," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Bullock, G., "Delphi Software Implementation of Model for System Survival Probability," January 2001.

Bullock, G., "Delphi Software Implementation of Model for Sustainability of a Platoon of Amphibious Vehicles," June 2001.

Gaver, D.P., "Operational Test and Evaluation," Web Site: <http://www.nps.navy.mil/opnsrsch/testeval/>

DoD KEY TECHNOLOGY AREAS: Human-Systems Interface, Modeling and Simulation

KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

DEVELOPMENT OF JOINT EXPERIMENTATION METHODOLOGY, HANDBOOK AND COURSEWARE

**Thomas H. Hoivik, Senior Lecturer
Department of Operations Research
Sponsor: U.S. Joint Forces Command**

OBJECTIVE: To develop a step-by-step joint experimentation planning and design methodology for U.S Joint Forces Command to use for planning and analysis of major Joint Experiments.

SUMMARY: Joint Experiments present a great opportunity for experimenting with new initiatives, which may include a variety of concepts, processes, or systems (CPS). However, there are mixed opinions about the value and validity of knowledge obtained during these past complex experiments. As a result, U.S. Joint Forces Command (J9) requested guidance on how to better plan, conduct and analyze complex joint experiments including the development of an experimentation handbook and courseware for training of participants. The research investigated and developed a detailed joint experimentation methodology including methods for identifying and fully defining concept, process or system issues and evaluation measures to gain insight into initiative effectiveness. The joint experimentation handbook and courseware introduced tools and techniques for better analysis, utilizing workshops, simulations and limited objective experiments, before large-scale wargames and complex joint and service experiments are conducted. The handbook will be used as a base reference and guide for future joint experimentation.

PUBLICATIONS:

Hoivik, T.H., "Fundamental of Joint Experimentation Planning and Design," U.S. Joint Forces Command (J9) Report, February 2002.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments

KEYWORDS: Joint Experimentation, Joint Forces Command, Joint Warfare

PROJECT SUMMARIES

JOINT INTEROPERABILITY TESTING OF THEATER MISSILE DEFENSE SYSTEMS: LAUNCH POINT ESTIMATION AND IMPACT POINT PREDICTION

Robert A. Koyak, Assistant Professor

Department of Operations Research

Robert G. Hutchins, Associate Professor

Department of Electrical and Computer Engineering

Sponsor: Defense Information Systems Agency, Joint Interoperability Test Command

OBJECTIVE: To characterize in physical and statistical terms the launch points and impact points of ballistic missiles detected during flight, and to use these results to develop criteria for joint interoperability testing of sensor platforms engaged in joint air and space surveillance.

SUMMARY: The investigation considered how tracking information that is communicated between sensor platforms during joint air and space surveillance exercises can be used to test the validity of reported missile launch points and impact points. The extent of this information is limited due to bandwidth constraints. Inaccurate estimates of launch and impact points, and inconsistent methodologies between sensor platforms, result in a disruptive common air picture that impairs interoperability. Much of the uncertainty in these quantities derives from unknown characteristics of the missile (e.g., the ballistic coefficient) that are difficult to estimate under practical tracking conditions. Using simulation and statistical theory, the investigation succeeded in developing criteria that can be used for interoperability testing purposes. Research on this project has continued into CY 2002.

PUBLICATIONS:

Herrin, R.R., Barrett, N.L., Baker, B.G. and Koyak, R.A., "Joint Theater Air and Missile Defense Interoperability Testing Capabilities and Challenges," *ITEA Journal of Test and Evaluation*, Vol. 22, pp. 31-40, June/July 2001.

Koyak, R.A. and Hutchins, G.R., "Joint Interoperability Testing of Theater Missile Defense Systems: Launch Point Estimation and Impact Point Prediction," Technical Report, submitted to the Joint Interoperability Test Command (draft).

THESIS DIRECTED:

Leffers, J.W., "Statistical Validation of Track Quality Numbers for Joint Interoperability Testing of Theater Air and Missile Defense Families of Systems," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Sensors

KEYWORDS: Missile, Sensor, Tracking, Surveillance

EXPLORING ANALYSIS OF COMBAT DATA

Thomas W. Lucas, Associate Professor

Department of Operations Research

Sponsor: Naval Postgraduate School

OBJECTIVE: Attempt to validate models and look for invariant trends in data sets on historical battles.

SUMMARY: This research explores the validation of Lanchester equations as models of the attrition process for the Battle of Kursk in World War II. The methodology and results of this study extend previous validation efforts undertaken since the development of the Ardennes Campaign Simulation Data Base (ACSDB) in 1989 and the Kursk Data Base (KDB) in 1996. The KDB is a computerized database developed by the Dupuy Institute and the Center for Army Analysis from military archives in Germany and Russia. The data are two-sided, time-phased (daily), highly detailed, and encompass 15 days of the campaign. Also, CAA's CDB90G data set, which contains about 140 attributes on nearly 660 land battles

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is being used to see what factors, over time, are associated with victory. Using classification trees, it was found that objective variables, by themselves, cannot explain the outcome of battles. Relative factors, such as leadership, have deep impacts on success. The classification models also reveal that the factors affecting battle outcomes have changed over time. A leadership advantage played an important role for hundreds of years. However, in the 20th century, air sorties, tanks, and intelligence showed a higher importance.

PUBLICATIONS:

Lucas, T. and Turkes, T., "Fitting Lanchester Equations to the Battle of Kursk," submitted to *Naval Research Logistics*, 2001.

THESIS DIRECTED:

Coban, M., "Predicting Battle Outcomes With Classification Trees," Masters Thesis, Naval Postgraduate School, December 2001.

Dinges, J., "Exploring the Validation of Lanchester Equations for the Battle of Kursk," Masters Thesis, Naval Postgraduate School, June 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Modeling and Simulation, Combat Analysis

CNET: PHASE III

David H. Olwell, Senior Lecturer
Department of Operations Research
Sponsor: Chief of Naval Education and Training

OBJECTIVE: Modify the Web-based content for OS2100 and deliver to NAVSEA using a mixture of instructional means.

SUMMARY: OS2100 has been previously prepared for Web-based delivery. In fall quarter, an opportunity arose to test the Web materials and simultaneously deliver the OS2100 course to four NAVSEA sites, using a mixture of on-site, video-teleconference, and web delivery methods. The materials were modified and the course was delivered. Student input indicates on-site instruction is preferred, that a mixture of modalities (Web, video, and on-site) is acceptable, and the Web-only is the last preference. Students whose duties resulted in travel during class periods depended on the Web materials to stay current, and many would not have completed the class without those materials being available. Different students had different learning styles, which resulted in differential use rates for the various course components. The lessons learned will be prepared in 2002 and disseminated.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

PROJECT SUMMARIES

OPTIMIZATION MODELING IN SUPPORT OF TANKER REQUIREMENTS STUDY FOR 2005 (TRS-05)

Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Department of Operations Research
LtCol Steven F. Baker, Associate Professor, U.S. Air Force Academy
Sponsor: Office of Secretary of Defense, Program Analysis and Evaluation

OBJECTIVE: To determine the number tanker airframes and aircrews needed to support the air mobility function in the years 2005 and beyond.

SUMMARY: Evaluation of tanker usage as well as overall system performance in the Weapons of Mass Destruction case has been completed. This analysis included excursions designed to analyze the effects of limited tanker forces, use of C130 aircraft as intra-theater shuttles, effects of limited fuel and airfield capacities. The analysis of tanker support for fighter drags is in progress. Model modifications and data analysis to support the fighter drag analysis is complete. The results of the fighter drag analysis are currently being validated with the help of Air Mobility Command personnel.

PUBLICATIONS:

Baker, S., Morton, D., Rosenthal, R. and Williams, L., "Optimizing Military Airlift, 2000," to appear in *Operations Research*, 2002.

Baker, S.F., Rosenthal, R. and Williams, L., *Tanker Requirements Study 2005: The Impact of Weapons of Mass Destruction Attack On Airlift Throughput*, Technical Report, Naval Postgraduate School.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Air Mobility, Aerial Refueling, Tankers, Mobilization

ADAPTIVE EXPLORATION OF AGENT-BASED COMMAND AND CONTROL SIMULATIONS

Susan Sanchez, Professor
Thomas W. Lucas, Associate Professor
Department of Operations Research
Sponsor: U.S. Marine Corps Combat Development Command

OBJECTIVE: Develop a framework that facilitates high-dimensional explorations of Agent-Based Command and Control Simulations.

SUMMARY: Analysts use combat models to provide information to decision-makers who must make and justify decisions involving billions of dollars and impacting many lives. Insights from combat models should be based on an ensemble of outcomes. This research helps build the foundation for a multi-year effort to define, test, and implement a new set of high-dimensional search strategies algorithms for use in exploring agent-based simulations. The prototype approaches that were developed automatically look across a breadth of factors and adaptively focus sampling efforts on the "interesting" effects and interactions. The efficiency of the search strategies under a variety of scenarios is being examined with computational experiments. These experiments are being conducted on known surfaces, using a stochastic response surface generator, and existing distillations.

PUBLICATIONS:

Lucas, T., Sanchez, S., Brown, L. and Vinyard, W., "Better Designs for High-Dimensional Explorations of Distillations," to appear in *Maneuver Warfare Science 2002*, Marine Corps Combat Development Command, Defense Automated Printing Service, 2002.

PROJECT SUMMARIES

Sanchez, S.M. and Lucas, T., "Agent-based Simulations: Simple Models, Complex Analyses," Invited paper to appear in *Proceedings of the 2002 Winter Simulation Conference*, Snowdon, J.L., Charnes, J., Chen, C-H and Yucesan, E. (eds.), Institute of Electrical and Electronic Engineers, Piscataway, NJ, 2002.

PRESENTATIONS:

Lucas, T.W. and Sanchez, S.M., "Adaptive High-Dimensional Explorations of Agent-based Command and Control Simulations," 11/01 – INFORMS, Miami, FL, November 2001.

Sanchez, S.M. and Lucas, T.W., "Exploring Agent-based Simulations: Simple Models, Complex Analyses," 11/01 – INFORMS, Miami, FL, November 2001.

Sanchez, S.M. and Lucas, T.W., "Adaptive Exploration of Project Albert Distillations," INFORMS International, Maui, HI, June 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Agent-Based Command and Control Simulations," INFORMS Military Applications Society 4th Annual International Meeting, Quantico, VA, May 2001.

THESIS DIRECTED:

Ho, K.J., "An Analysis of Distributed Combat Systems," Masters Thesis, Naval Postgraduate School, December 2001.

Vinyard, W.C., "Reducing Non-monotonicities in Combat Models," Masters Thesis, Naval Postgraduate School, September 2001.

OTHER:

Vinyard, B. and Lucas, T., "Exploring Combat Models for Non-monotonicities and Remedies," submitted to *PHALANX*.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Modeling and Simulation

KEYWORDS: Modeling and Simulation, Design of Experiments, Agent-based Models, Command, Control and Communications

CNET: PHASE III
Susan Sanchez, Professor
Department of Operations Research
Sponsor: Chief of Naval Education and Training

OBJECTIVE: Adapt the interactive computer cases and games to be used in a web-based course on operations analysis. Specifically, the goals were to make the modules for this Web-based course more user friendly, and to change the contexts from generic routing and distribution problems to military applications. This is a continuation of CNET: OPERATIONS ANALYSIS.

SUMMARY: Three software modules were added to the course materials for OS3000: Introduction to Management Science for Information Systems and Operations (ISO). Instructions for student assignments were written, and related topics were integrated into questions for the course's weekly web discussion board. The first module is an agent-based simulation that introduces the students to some basic concepts in simulation and experimental design by allowing them to investigate the efficacy of different command and control structures on a peacekeeping operation. The second module introduces the students to inventory control, and the impact that various ordering policies, lead times, and demand distributions have on both

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total costs and the fill-rate. The third module motivates the use of shortest-path and min-low/max-cut problems for network interdiction. The basic software tools, instructions, and assignments were put in place during Fall 2001. Graphics enhancements continued through Winter 2002.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

DISTRIBUTED LEARNING: OPERATIONS ANALYSIS

Susan Sanchez, Professor

Department of Operations Research

Sponsor: Chief of Naval Education and Training

OBJECTIVE: Develop a framework for a case-oriented management science course for the ISO curriculum. Web-based elements of the course should both (1) form the basis for a high-quality, relevant distributed learning course for non-resident ISO students, and (2) enhance the learning experience for resident ISO students.

SUMMARY: The structure for online course delivery was put in place for OS3000: Introduction to Management Science for Information Systems and Operations (ISO). The course was offered as a web-enhanced course to resident students at NPS during Spring 01. Interactive java applets and computer games were used to illustrate the quantitative modeling framework for a variety of topics, such as inventory management, resource allocation, routing, scheduling, network interdiction, and network reliability. Web-based courseware distributed software, slides, and other course content, while Web discussion boards provided a forum for instructor-learner and learner-learner interactions. The team-based course structure provided the students with hands-on experience in defining problems, developing appropriate quantitative models, defending their model choices, and effectively communicating the results. Military examples were used to motivate the material, and ties to examples and scenarios from previous ISO coursework were put in place. Student teams were also responsible for preparing briefings on recent ISO applications that used tools related to those covered in class. Course development continued in CNET Phase III.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Distributed Learning, Web-Based Learning, Distance Learning

ECONOMIC BENEFIT OF NAVAL FORWARD PRESENCE

David A. Schrady, Distinguished Professor

Department of Operations Research

R.L. Looney, Professor

Douglas Porch, Professor

Department of National Security Affairs

Sponsor: Chief of Naval Operation (N81)

OBJECTIVES: To develop an integrated framework for assessing the consequences of globalization on the market forces associated with naval forward presence and crisis response. This task will draw heavily on the expanding literature on globalization, integrating it with our quantitative findings on economic benefits.

SUMMARY: This study develops an integrated framework for assessing the consequences of globalization on the market forces likely to be affected by naval forward presence and crisis response. The study demonstrates that it is possible to develop an operational definition for quantifying globalization. The study found a clear linkage between the highly globalized countries and the manner in which oil shocks affect their economies. Over time, highly globalized countries including the United States have become more vulnerable to oil price shocks. Because naval forward presence and crisis response tends to suppress

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oil shocks and return prices to their equilibrium levels, the role of naval activities in economic stabilization has not only taken on increased importance in recent years but, with the likely continuation of global trends, should play an even greater positive economic role for the United States in the foreseeable future.

PUBLICATIONS:

Looney, R.E., Schrady, D.A., et al., "Estimating Economic Benefits of Naval Forward Presence: A Brief Summary," *Proceedings of Conference on Globalization and Naval Forward Presence*, Ch. 3, Institute for National Security Studies, National Defense University, Washington, DC, 19 April 2001.

Looney, R.E., Schrady, D.A. and Brown, R.L., "Estimating the Economic Benefits of Forward-Engaged Naval Forces," *Interfaces*, Vol. 31, No. 4, July-August 2001.

Looney, R.E., Schrady, D.A. and Porch, D., *Economic Impact of Naval Forward Presence: Benefits, Linkage and Future Prospects as Modified by Trends in Globalization*, Naval Postgraduate School Technical Report, NPS-NSOR-02-001, December 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Naval Forward Presence, Economic Benefits, Econometrics, Globalization

MODELING AND SIMULATION ANALYSIS FOR EXPEDITIONARY LOGISTICS

David A. Schrady, Distinguished Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVES: The objective is to support Metron, Inc. and Lockheed Martin who, separately, hold contracts for modeling and simulation of expeditionary logistics in support of the Future Naval Capabilities program of the Office of Naval Research.

SUMMARY: The effort has consisted of support and analyses defining and documenting logistics command and control, modeling and simulation, database, planning, and user interface requirements responsive to the ONR Future Naval Capabilities Expeditionary Logistics vision. It has further involved determination of the logistics representation enhancements needed in the Naval Simulation System in order to meet these requirements. Monthly activity reports were provided to both contractors for inclusion in their monthly reports to ONR.

PRESENTATION:

Schrady, D.A., "Combat Logistics," Commander Naval Forces Korea, Commanders Conference, Port Hueneme, CA, 10 February 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Sustainability, Sea-Based Logistics, Expeditionary Logistics, Expeditionary Maneuver Warfare

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RESEARCH ON AGGREGATED COMBAT MODELS II – METHODOLOGY FOR THE COMPARATIVE EVALUATION OF MODELS

**James G. Taylor, Professor
Department of Operations Research**

Sponsor: United States Army – Dismounted Battlespace Battle Lab (DBBL)

OBJECTIVE: To improve quantitative methodology for assisting in the selection of aggregated-force combat models and submodels, particularly for the attrition process. Also, to improve attrition methodologies for such models.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Combat Models, Evaluation of Combat Models, Attrition Methodologies

SUPPORT OF JCATS LIMITED V&V

**James G. Taylor, Professor
Department of Operations Research**

Sponsor: United States Army – Dismounted Battlespace Battle Lab (DBBL)

OBJECTIVE: Assist in the conduct of a limited verification and validation (V&V) of the non-lethal capabilities of the joint conflict and tactical simulation (JCATS). Primary attention is to be given to the verification of JCATS algorithms, particularly those for simulating the capabilities of non-lethal weapons (NLW).

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Model Verification/Validation, Non-Lethal Effects, Simulation of Joint Warfare

SUPPORT OF PA&E CAMPAIGN MODEL PROGRAM (PAEP) (UPGRADING GROUND-COMBAT ATTRITION AND MOVEMENT AND IMPROVING TREATMENT OF UNCERTAINTIES)

**James G. Taylor, Professor
Department of Operations Research**

Sponsor: Office of the Secretary of Defense

OBJECTIVE: Provide support for upgrading the PA&E campaign model program (PAEP) with the addition of a ground-force model (that is consistent with overall PAEP goals) and also for improving the treatment of uncertainties.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Weapons Scoring/Aggression, Ground-Combat Attrition, Ground-Force Movement

UPGRADING GROUND-COMBAT ATTRITION AND MOVEMENT FOR ITEM

**James G. Taylor, Professor
Department of Operations Research**

Sponsor: Defense Threat Reduction Agency

OBJECTIVE: Work closely with time developer (SAIC) to improve assessment algorithm for direct-fire ground-combat attrition in item. The new single-weapon-system-type kill rates recently developed by the proposed principal investigator would be basis with this upgrade.

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DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Stand-Alone Attrition Methodol, Lanchester Attrition-Rate COEF, Direct-Fire Ground-Combat ATTR, Indirect-Fire Ground-Combat AT

LP/POMDP INFORMATION OPTIMIZATION METHODOLOGY

Alan Washburn, Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Develop and test an optimization method for jointly assigning sensor assets and firepower assets to a target set. The method will employ Linear Programming and Partially Observable Markov Decision Processes to generate policies for joint, sequential assignments.

SUMMARY: Current theory is extended to include the effects of surveillance, as well as the effects of BDA (bomb damage assessment). A computer program JOIST has been produced that achieves solutions in minutes to hours for realistically scaled problems, depending on desired accuracy. The scenario considered by JOIST is one where sorties must be assigned to targets in an environment where information about the effects of strikes is expensive and imperfect, and where one effect of a sortie may be to discover new, previously unknown targets. Expected total target value killed is maximized while constraints on the availability of sorties and acceptable attrition are observed. The methodology is suitable for investigating the relative benefits of information and strike assets, and possibly for helping to construct air tasking orders. Efforts in the second year (2002) will be devoted to improving efficiency, and to transitioning JOIST to practical purposes.

PUBLICATIONS:

Washburn, A., *JOIST: Joint Optimizing Informational Strike Tool*, Naval Postgraduate School Project Report, NPS-OR-02-001-PR, 2001.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: BDA, POMDP, Information

C130 TRAINING MODEL

Laura M. Williams, Research Assistant Professor

Department of Operations Research

Sponsor: 314th Airlift Wing, Little Rock Air Force Base

OBJECTIVE: The primary objective of this project is to provide a model, i.e., an automated tool, to create operational aircrew training schedules of varying time horizons for individual crewmembers in a variety of syllabi.

SUMMARY: The primary scheduling model, a set of mixed-integer programs designed to create good schedules in a reasonable amount of time, has been completed and is currently being thoroughly tested. Documentation and programming of a user interface are in progress. The user interface, joint work with the sponsor, is being designed to take advantage of the user's current data environment to make the model as easy as possible to use on a regular basis.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Scheduling, Training

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LARGE-SCALE MIXED INTEGER PROGRAMMING

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Joint Warfare Analysis Center

OBJECTIVE: Develop integer-programming methods, including decomposition, for solving interdiction problems under uncertainty.

SUMMARY: Available from sponsor.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

SUPPORT FOR REAL-TIME EXECUTION DECISION SUPPORT (REDS)

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Office of Naval Research

OBJECTIVE: Provide technical support for the strike-planning and execution system (REDS, Real-time Execution Decision Support) being developed as the Space and Naval Warfare Systems Command, San Diego. Areas of interest include predicting locations of mobile targets, optimization of aircraft-to-target assignments and route planning.

SUMMARY: Potential techniques for predicting locations of mobile targets were explored. For purposes of familiarization, the PI visited Fallon Naval Air Station to observe how element-level strike planning is currently carried out; the execution of the planned strike was also observed.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH,

NATIONAL SECURITY AGENCY

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: National Security Agency

OBJECTIVE: Provide on-call analytical support to the National Security Agency.

SUMMARY: Available from sponsor.

THESES DIRECTED:

Bingol, L., "A Lagrangian Heuristic for Solving a Network Interdiction Problem," Masters Thesis, Naval Postgraduate School, December 2001.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

**DEPARTMENT OF
OPERATIONS RESEARCH**

**2001
Faculty Publications
and Presentations**

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Brown, G., Keegan, J., Vigus, B., and Wood, K., "The Kellogg Company Optimizes Production, Inventory, and Distribution," *Interfaces*, Vol. 31, pp. 1-15, 2001.

Herrin, R.R., Barrett, N.L., Baker, B.G., and Koyak, R.A., "Joint Theater Air and Missile Defense Interoperability Testing Capabilities and Challenges," *ITEA Journal of Test and Evaluation*, Vol. 22, pp. 31-40, June/July 2001.

Hohzaki, R. and Washburn, A., "The Diesel Submarine Flaming Datum Problem," *Military Operations Research*, Vol. 6, No. 4, pp. 19-30, 2001.

Looney, R.E., Schrady, D.A. and Brown, R.L., "Estimating the Economic Benefits of Forward-Engaged Naval Forces," *Interfaces*, Vol. 31, No. 4, July-August 2001.

Marín, A. and Salmerón, J., "A Risk Function for the Stochastic Modeling of Electric Capacity Expansion," *Naval Research Logistics*, Vol. 48, pp. 662-683, 2001.

Schrady, D.A., "Golden Anniversary (of the NPS OR Program)," *ORMS Today*, Vol. 28, No. 1, February 2001.

Washburn, A., "A New Kind of Fictitious Play," *Naval Research Logistics*, Vol. 48, pp. 270-280. 2001.

Washburn, A., "Bits, Bangs, or Bucks? The Coming Information Crisis," *PHALANX*, Vol. 34, No. 3 (part I) and No. 4 (part II), 2001.

CONFERENCE PAPERS

Buttrey, S.E., Nolan, D. and Temple Lang, D., "An Environment for Creating Interactive Statistical Documents," *Proceedings of the 33rd Symposium on the Interface of Computing Science and Statistics*, Costa Mesa, CA, 13-16 June 2001.

Looney, R.E. and Schrady, D.A., et al., "Estimating Economic Benefits of Naval Forward Presence: A Brief Summary," *Proceedings of Conference on Globalization and Naval Forward Presence*, Ch. 3, Institute for National Security Studies, National Defense University, Washington D.C., 19 April 2001.

Marín, A. and Salmerón, J., "Modelización Conjunta para la Localización de Facilidades y Expansión de Capacidad," *Annals of the JAIIQ*, edited by SADIO, Vol. 30, pp. 94-101, Buenos Aires, Argentina, 2001.

Sanchez, S.M., "ABC's of Output Analysis," *Proceedings of the 2001 Winter Simulation Conference*, Peters, B.A., Smith, J.S., Medeiros, D.J. and Rohrer, M.W. (eds.), pp. 30-39. Institute of Electrical and Electronics Engineers, Piscataway, NJ, 2001.

Sanchez, S.M. and Hynes, G.E., "Perception and Assessment of Online Communication Skill Acquisition," *Proceedings of the Fall 2001 Symposium on Assessing Online Instruction*, Monterey, CA, October 2001.

CONFERENCE PRESENTATIONS

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

PUBLICATIONS/PRESENTATIONS

Bradley, G., "M&S in Classroom Instruction and Thesis Research at the Naval Postgraduate School," NAVMSMO Technical Interchange Meeting, National Defense University, Ft. McNair, Washington, DC, 23 August 2001.

Bradley, G. and Buss, A., "Demonstration System for a Military Mission," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Bradley, G. and Buss, A., "Loosely Coupled Components for Near Real Time Modeling and Optimization," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Brown, G., Byrne, P. and Washburn, A., "The Fast Theater Model," 69th Military Operations Research Symposium, U. S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Brown, G.G., Newman, A.M., Rosenthal, R.E and Rowe, A.A., "Optimizing Tomahawk Strikes," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Tarantino, W.J., "Optimal Stationing of Army Forces," National Meeting of the Institute for Operations Research and the Management Sciences, Miami, FL, 4-7 November 2001.

Dell, R.F. and Noble, J.D., "Scheduling and Distributing Intra-Theatre Wartime POL Requirements," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Dell, R.F. and Brown, G.G., "Tutorial on Optimizing Military Capital Budgeting," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Gaver, D.P., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A. and Takahara, G., "On Service of Time-Limited Tasks with Uncertain Outcomes (Uncertain Time-Critical Tasking)," XXI International Seminar on Stability Problems for Stochastic Models, Eger, Hungary 28 January-3 February 2001.

Gaver, D.P., Jacobs, P.A. and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution" European Safety and Reliability Conference, Turino, Italy, 16-20 September 2001.

Gaver, D.P., Jacobs, P.A., Carpenter, R.L., Robinson, P. and Bobb, A., "Towards a Model of Liver Insult and Recovery After Insult by Xenobiotic Chemicals," Poster Session, 40th Annual Meeting, Society of Toxicology, San Francisco, CA, 24-29 March 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Agent-Based Command and Control Simulations INFORMS Military Applications Society 4th Annual International Meeting, Quantico, VA, May 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Command and Control Simulations," Military Applications Society 4th Annual Meeting, Quantico, VA, 21-23 May 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive Exploration of Project Albert Distillations," INFORMS International 2001, Maui, HI, 17-20 June 2001.

Lucas, T.W. and Sanchez, S.M., "Adaptive High-Dimensional Explorations of Agent-based Command and Control Simulations," INFORMS National Meeting, Miami, FL, 4-7 November 2001.

Lucas, T.W. and Sanchez, S.M., "Exploring Agent-based Simulations: Simple Models, Complex Analyses," 11/01 - INFORMS, Miami, FL, November 2001.

PUBLICATIONS/PRESENTATIONS

Morton, D., Salmerón, J. and Wood, K., "A Sampling-Based Cutting-Plane Method for Stochastic Programming," INFORMS International Hawaii, Maui, HI, 17-20 June 2001.

Morton, D., Salmerón, J. and Wood, K., "A Stochastic Program for Optimizing Military Sealift subject to Attack," Workshop on Decision-Making Under Uncertainty, Molde, Norway, 18-20 May 2001.

Morton, D., Salmerón, J. and Wood, K., "Optimizing Military Sealift Subject to Attack," INFORMS National Meeting, Miami Beach, FL, 4-7 November 2001.

Sanchez, S.M. and Lucas, T.W., "Adaptive Exploration of Project Albert Distillations," INFORMS International, Maui, HI, June 2001.

Sanchez, S.M. and Lucas, T.W., "Adaptive High-Dimensional Explorations of Agent-based Command and Control Simulations," 11/01 – INFORMS, Miami, FL, November 2001.

Sanchez, S.M. and Lucas, T.W., "Exploring Agent-Based Simulations: Simple Models, Complex Analyses," INFORMS National Meeting, Miami, FL, 4-7 November 2001.

Sanchez, S.M. and Wood, R.K., "Solving Stochastic Network Interdiction Problems with the Partially Enumerate then Screen Method," INFORMS International 2001, Maui, HI, 17-20 June 2001.

Sanchez, S. and Wood, K., "Stochastic Network Interdiction," Air Force Office of Scientific Research PI Meeting, Minnowbrook, NY, 11-13 November 2001.

Schrady, D.A., "Combat Logistics," Commander Naval Forces Korea, Commanders Conference, Port Hueneme, CA, 10 February 2001.

Tarantino, W.J, Dell, R.F. and Connor, G., "Optimal Stationing of Army Forces (OSAF)," 69th Military Operations Research Society Symposium, U.S. Naval Academy, Annapolis, MD, 12-14 June 2001.

Wood, R.K. and Sanchez, S.M., "Solving Stochastic Network Interdiction with the BEST Algorithm," AFOSR PI Meeting, Minnowbrook, NY, 2001.

TECHNICAL REPORTS

Baker, S.F., Rosenthal, R.E. and Williams, L., *Tanker Requirements Study 2005: The Impact of Weapons of Mass Destruction Attack on Airlift Throughput*, Naval Postgraduate School Technical Report, June 2001.

Brown, G.G., Newman, A.M, Rosenthal, R.E. and Rowe, A.A., *Optimizing Tomahawk Strikes*, Naval Postgraduate School Technical Report, NPS-OR-01-001-PR, January 2001, (also appeared in *Naval Postgraduate School Research Newsletter*).

Gates, W. and Washburn, A., *The Navy Operational Support Aircraft Fleet*, Naval Postgraduate School Technical Report, NPS-OR-01-006-PR, 2001.

Gaver, D.P, Jacobs, P.A. and Kemp, J., *Modeling the Operation of a Platoon of Amphibious Vehicles for Support of Operational Test and Evaluation (OT&E)*, Naval Postgraduate School Technical Report, NPS-OR-01-009, July 2001.

Gaver, D.P., Jacobs, P.A., and Seglie, E., *Stochastic Models for Promoting and Testing System Reliability Evolution*, Naval Postgraduate School Technical Report, NPS-OR-01-011, September 2001.

PUBLICATIONS/PRESENTATIONS

Glazebrook, K.D., Gaver, D.P., and Jacobs, P.A., *On a Military Scheduling Problem*, Naval Postgraduate Technical Report, NPS-OR-01-010, August 2001.

Looney, R.E, Schrady, D.A. and Porch, D., *Economic Impact of Naval Forward Presence: Benefits, Linkage and Future Prospects as Modified by Trends in Globalization*, Naval Postgraduate School Technical Report, NPS-NS-02-001, December 2001.

Washburn, A., *JOIST: Joint Optimizing Informational Strike Tool*, Naval Postgraduate Technical Report, NPS-OR-02-001-PR, 2001.

Washburn, A., *The Fast Theater Model (FATHM)*, Naval Postgraduate School Technical Report, NPS-OR-01-002-PR, 2001.

CONTRIBUTION TO BOOK

Gaver, D.P., Jacobs, P.A., and Seglie, E., "Stochastic Models for Promoting and Testing System Reliability Evolution," *Safety & Reliability: ESREL 2001 Towards a Safer World*, E. Zio, M. Demichela, N. (eds.), Piccinini, Politecnico di Torino, Vol. 2, pp. 1109-1116, 2001.

OTHER

Bullock, G., "Delphi Software Implementation of Model for System Survival Probability," January 2001.

Bullock, G., "Delphi Software Implementation of Model for Sustainability of a Platoon of Amphibious Vehicles," June 2001.

Gaver, D.P., "Operational Test and Evaluation," Web Site: <http://www.nps.navy.mil/opnsrsch/testeval/>

**DEPARTMENT OF
OPERATIONS RESEARCH**

Thesis Abstracts

THESIS ABSTRACTS

EXPLOITING CONSECUTIVE ONES STRUCTURE IN THE SET PARTITIONING PROBLEM

Mehmet Ayik-Lieutenant, Turkish Navy

B.S., Turkish Naval Academy, 1992

M.S., Naval Postgraduate School, 1998

Doctor of Philosophy in Operations Research-December 2000

Advisor: Gerald G. Brown, Department of Operations Research

The Set Partitioning Problem (SPP) is one of the most extensively researched models in integer optimization, and is widely applied in operations research. SPP is used for crew scheduling, vehicle routing, stock cutting, production scheduling, and many other combinatorial problems. The power and generality of SPP come at a price: An SPP can be very difficult to solve. A real-world SPP often has columns, or rows, with long strings of consecutive ones. This is exploited this with a new preprocessing reduction that can eliminate some variables. A column-splitting technique is also introduced to render a model that can be solved directly or used to bound SPP with Lagrangian relaxation or an exterior penalty method. An SPP row-splitting method is developed that yields a special model that Bender's decomposition may then solve faster than the monolithic SPP. These techniques are demonstrated with well-known test problems from airlines and other researchers. A new U.S. Navy aircraft carrier long-term deployment scheduling model is contributed, using the new techniques to plan with weekly fidelity over a ten-year planning horizon. This improved time fidelity increases planned deployment coverage of areas of responsibility by about ten carrier weeks.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Computing and Software, Surface/Undersurface Vehicles-Ships and Watercraft

KEYWORDS: Set Partitioning, Consecutive Ones, Preprocessing, Problem Size Reduction, Set Packing, Lagrangian Relaxation, Subgradient Optimization, Penalty Method, Benders Decomposition, Aircraft Carrier, Optimization

AN ALGORITHM FOR ENUMERATING THE NEAR-MINIMUM WEIGHT S-T CUTS OF A GRAPH

Ahmet Balcioglu-First Lieutenant, Turkish Army

B.S., Turkish Army Military Academy, 1993

Master of Science in Operations Research-December 2000

Advisors: R. Kevin Wood, Department of Operations Research

Craig W. Rasmussen, Department of Mathematics

Second Reader: Gerald G. Brown, Department of Operations Research

An algorithm for enumerating near-minimum weight s-t cuts in directed and undirected graphs, with applications to network interdiction and network reliability is provided. "Near-minimum" means within a factor of $1 + \epsilon$ of the minimum for some $\epsilon > 0$. The algorithm is based on recursive inclusion and exclusion of edges in locally minimum-weight cuts identified with a maximum flow algorithm. A polynomial-time complexity result when $\epsilon = 0$, and for $\epsilon > 0$ the demonstration of good empirical efficiency is proven. The algorithm is programmed in Java, run on a 733 MHz Pentium III computer with 128 megabytes of memory, and tested on a number of graphs. For example, all 274,550 near-minimum cuts within 10% of the minimum weight can be obtained in 74 seconds for a 627 vertex 2,450 edge unweighted graph. All 20,806 near-minimum cuts within 20% of minimum can be enumerated in 61 seconds on the same graph with weights being uniformly distributed integers in the range [1,10].

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Near-Minimum Cuts, Cut Enumeration, Minimum Cuts, Network Interdiction

THESIS ABSTRACTS

OPTIMIZING PROCUREMENT PLANNING OF NAVY SHIPS AND AIRCRAFT

Nihat Baran-Lieutenant Junior Grade, Turkish Navy

B.S., Turkish Naval Academy, 1995

Master of Science in Operations Research-December 2000

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

The United States Navy Chief of Naval Operations Assessment Division (N81) is responsible for planning long-range capital expenditure on ships, submarines and aircraft. This planning is complicated, involves billions of dollars over decades, and determines future Navy capability. Navy force structure analysts have to balance: yearly budgets; requirements, current inventory, and procurement options for ships, submarines, and aircraft; and capacity and workforce levels of shipyards and factories. N81 Navy analysts currently use the Extended Planning Annex/Total Obligated Authority (a spreadsheet that estimates the financial impact of any complete future plan) to assist them with their complex planning. The Capital Investment Planning Aid (CIPA) is a prototypic optimization model, limited in scale, previously developed to demonstrate the benefits of augmenting EPA/TOA with optimization. This thesis introduces Generalizing Procurement Planning for Naval Ships and Aircraft (GENSA), which extends CIPA. GENSA is tested with a 30-year planning horizon with 29 mission areas, 45 ship classes, 39 aircraft types, 13 production facilities, and four categories of money. A current base case and an excursion demonstrate GENSA can be used to address exigent issues optimally.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Programming, Military Capital Budgeting, Optimization, Force Structure

APPLICATION OF A SYSTEM-BASED INVENTORY MODEL FOR MARINE CORPS REPAIRABLE PARTS

Craig P. Barnett-Captain, United States Marine Corps

B.S., United States Naval Academy, 1992

Master of Science in Operations Research-September 2001

Advisor: Kevin R. Gue, Graduate School of Business and Public Policy

Second Reader: David A. Schrady, Department of Operations Research

A critical component of the Marine Corps' self-sustainment capability is its ability to procure and repair components for its ground equipment fleets. Secondary repairables consist of components that can be repaired, and for which repair is generally more economical and timely than purchase. The Marine Corps currently maintains spare repairable parts at seven principal locations, each operating independently of the other. There is excess inventory Service-wide because of the isolation of the inventories and because of mathematical flaws in the Marine Corps' sparing methodology. The Marine Corps is seeking to centralize the management of secondary repairables and is considering options that include centralizing responsibility and funding (while keeping the inventory model as it is) and changing the inventory model as well as the responsibility and funding. This thesis demonstrated that a centralized, "enterprise-wide" model of the inventory is superior to a decentralized one. Measures of comparison are total inventory cost and end-item availability. Stock levels calculated by both the current model and a commercial application called VMetric^(tm)-XL were evaluated. For a selected end-item, the current model produces stock levels totaling \$25.9M in inventory and achieves 89.1% availability. For the same level of availability, VMetric recommends stock levels totaling \$2.9M, a stunning 89% reduction in cost. These results are explained and implications for Marine Corps logistics support are suggested.

DoD KEY TECHNOLOGY AREAS: Manufacturing, Science and Technology

KEYWORDS: System-Based Inventory, Marine Corps, Self-Sustainment Capability, Repairable Parts

THESIS ABSTRACTS

ANALYSIS OF SELF-REPORTED SLEEP PATTERNS IN A SAMPLE OF U.S. NAVY

SUBMARINERS USING NONPARAMETRIC STATISTICS

Simonia Ridley Blassingame-Lieutenant, United States Navy

B.S., Spelman College, 1992

M.S., Troy State University, 1999

Master of Science in Operations Research-September 2001

Advisor: Nita L. Miller, Department of Operations Research

Second Reader: Robert A. Koyak, Department of Operations Research

Fatigue contributes to increased accidents and mishaps and reductions in human performance. Inadequacies in the quality and quantity of sleep amongst U.S. Navy submariners can have detrimental effects on command and control functions, and can degrade overall human performance. The purpose of this study is to gain insight into the sleeping habits of U.S. Navy submariners. Using data supplied by the Naval Submarine Medical Research Laboratory, this study evaluates what a sub-sample of this population think about their sleep habits and will determine if there are differences in the reported amount of sleep between sailors in four different operational environments: 1) at sea, 2) in port, 3) on shore duty, and 4) on leave. The statistical analysis showed that there are discernable differences in the quality and quantity of sleep onboard U.S. submarines. There is a positive correlation between the amount of sleep obtained and the desired amount of sleep to function at every operational condition. Of the four operational conditions evaluated, the 'at sea' condition is the most different from all other conditions. Submariners reported getting less sleep while 'at sea' than other conditions. Finally, there is a positive correlation between the amounts of sleep obtained (both total sleep and uninterrupted sleep) and the desired amounts of sleep needed to function in every operational condition leading to the inference that subjects who report needing more sleep do indeed get more sleep. When in the 'at sea' condition, this correlation was much weaker indicating that subjects have much less control over the amount of sleep they get when deployed.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Human Performances, Sleep Patterns, Fatigue, Submariners

OPTIMIZING THE NUMBER AND EMPLOYMENT OF COMBAT LOGISTICS FORCE

SHUTTLE SHIPS, WITH A CASE STUDY OF THE T-AKE SHIP

Kevin D. Borden-Lieutenant, United States Navy

B.S., United States Naval Academy, 1994

Master of Science in Operations Research-September 2001

Advisor: Gerald G. Brown, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

An optimization model that prescribes how Combat Logistics Force shuttle ships --- such as the new T-AKE 1 Lewis & Clark class auxiliary cargo-and-ammunition ship --- should be employed to sustain any number of deployed aircraft carrier (or other) battle groups (BGs) throughout a major theater war are presented. A variety of unclassified deterministic scenarios are developed involving between one and six BGs transiting worldwide to, e.g., the Baltic, the Arabian Sea, or Korea. Daily consumption of dry stores, ship fuel, aviation fuel, and ordnance is estimated. For each shuttle ship, it is assumed that the first consolidation visit to a BG can occur anywhere, but thereafter we track the shuttle ship back to a port to reload is tracked, and then back to rendezvous with some BG, and so forth. To precisely account for transit times, a global sea route model is presented that connects all resupply ports to waypoints, and distinguishes slow-speed passages through canals and restricted waterways, and legs that preclude BG consolidation visits. The objective is to deliver maximal quantities, and to avoid ever falling below BG safety stocks. The results tell how many shuttle ships are needed, and how to employ them.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Optimization, Combat Logistics Force Shuttle Ships, T-AKE Ship

THESIS ABSTRACTS

THE IMPACT OF TURN AROUND TIME IN BRAZILIAN NAVY INVENTORIES

Mauricio Casagrande-Commander, Brazilian Navy

B.S., Brazilian Navy Academy, 1979

Master of Science in Management-December 2000

Advisors: Kevin R. Gue, Department of Systems Management

CDR Kevin J. Maher, USN, Department of Operations Research

This thesis analyzes how the operation of helicopters produced and supported by manufacturers in various countries affect Brazilian Navy repairable inventories levels and costs. The research is based on a scenario where the Brazilian Navy operates 68 helicopters, manufactured by contractors in the U.S., France, England and Italy, and the Brazilian Navy relies on these manufacturers for depot-level maintenance. A simulation model representing the repair process of a group of critical helicopter components and measure the turn-around time (TAT) was developed. A readiness based model was also developed to find the optimal inventory level of the selected group of helicopter components to achieve a desired operational availability under these TATs. The results were applied to a spreadsheet model to find the differences in spare levels and associated costs necessary to operate the helicopter fleet. The research concludes that the helicopter's source has a substantial impact on repairable inventories levels and costs. Furthermore, this impact is large enough to influence decisions in the Brazilian Navy acquisition process of equipment and weapons systems.

DoD KEY TECHNOLOGY AREA: Manufacturing, Science and Technology, Other (Logistics)

KEYWORDS: Inventory Management, Operational Availability, Simulation Modeling, Transportation, Aviation Depot-Level Maintenance

ESTIMATING HULL COATING THICKNESS DISTRIBUTIONS USING THE EM ALGORITHM

Michael A. Corriere-Lieutenant, United States Navy

B.S., United States Naval Academy, 1988

M.B.A., University of New Mexico, 1994

Master of Science in Operations Research-December 2000

Advisor: Lyn R. Whitaker, Department of Operations Research

Second Reader: Robert R. Read, Department of Operations Research

The underwater hull coating system on surface ships is comprised anti-corrosive (AC) and anti-fouling (AF) paint. The AF layers are designed to wear away, continuously leaching cuprous oxide to inhibit marine growth. The thickness of the AF paint layers determines the expected service life of a coating system. Thus, it is important to assess the thickness of the AF layers to determine if the current hull coating system is sufficient. The Naval Ship Technical Manual (NSTM) provides specific guidelines as to how much AF paint should be applied. Unfortunately, the AF layers cannot be measured directly. The distribution of total paint thickness measurements is currently used as a proxy for the distribution of the thickness of the AF paint layers when determining if the existing coating system meets the hull coating requirements. A remedy for this situation is proposed. A non-parametric maximum likelihood estimator for the cumulative distribution function of the AF layers, based on the EM algorithm, has been developed. Monte Carlo simulation is used to study the properties of this statistical approach for estimating the AF thickness. This model can be used to help decide if sufficient AF paint is on the underwater hull of a ship.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures, Ships and Watercraft

KEYWORDS: Deconvolution, EM Algorithm, Anti-Fouling Paint, Underwater Hull Coating System

THESIS ABSTRACTS

PERFORMANCE METRICS FOR CORRELATION AND TRACKING ALGORITHMS

Nathan S. Dietrich-Captain, United States Army

B.S., University of South Dakota, 1987

Master of Science in Operations Research-June 2001

Advisor: Robert A. Koyak, Department of Operations Research

Second Reader: Thomas W. Lucas, Department of Operations Research

Military commanders require situational awareness to support real-time decision-making. To obtain information on possibly hostile entities in an area of interest, surveillance systems, which receive information from sensors such as radars, intelligence, and other sources, are often used. One of the objectives of surveillance systems that track aircraft is the formation of a Single Integrated Air Picture (SIAP), that represents a coherent resolution of information. Correlation is the process by which sensor measurements and other information are combined to keep the SIAP up-to-date in real time. A correlator, which is the software implementation of a correlation methodology, must resolve ambiguities and conflicting information to provide an operationally useful synthesis of surveillance data. Possible ambiguities include missed tracks, extra tracks, or position and velocity errors. The metrics developed in this thesis are designed for use in evaluating the performance of air surveillance systems, of which correlators are an integral part. Maneuvering or closely spaced aircraft pose difficult issues for air surveillance systems. These are addressed by the performance metrics. Using scripted test scenarios in a modeling and simulation environment, comparisons of correlators can be made using nonparametric statistical methods. An experiment constructed in this manner can be used to support acquisition decision-making.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Modeling and Simulation, Sensors

KEYWORDS: Correlator, Correlator Performance Metrics, Surveillance Systems, Single Integrated Air Picture (SIAP)

EXPLORING THE VALIDATION OF LANCHESTER EQUATIONS FOR THE BATTLE OF KURSK

John A. Dinges-Captain, United States Army

B.S., United States Military Academy, 1991

Master of Science in Operations Research-June 2001

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: LTC Eugene P. Paulo, USA, Department of Operations Research

This thesis explores the validation of Lanchester equations as models of the attrition process for the Battle of Kursk in World War II. The methodology and results of this study extend previous validation efforts undertaken since the development of the Ardennes Campaign Simulation Data Base (ACSDB) in 1989 and the Kursk Data Base (KDB) in 1996. The KDB is a computerized database developed by the Dupuy Institute and the Center for Army Analysis from military archives in Germany and Russia. The data are two-sided, time-phased (daily), highly detailed, and encompass 15 days of the campaign. The primary areas of analysis are the effect of using purely engaged forces in parameter estimation and the effect of force weighting in forming homogeneous force strengths. Based on the numbers of personnel, tanks, armored personnel carriers, and artillery, three different data sets were constructed: all combat forces in the campaign, combat forces within contact that are both engaged and not engaged, and combat forces within contact that are engaged. In addition, a weight optimization program using a steepest ascent algorithm was developed and utilized. Findings indicate that Lanchester-based models provide a considerably better fit for data sets composed only of forces that are actively engaged. Also, Lanchester's linear model appears to provide the best fit to the Battle of Kursk data. Finally, optimization of force weights does not significantly improve the fit of Lanchester models.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Lanchester Equations, Battle of Kursk, Combat Models, Attrition, Model Validation

RE-ENGINEERING THE ENROLLMENT MANAGEMENT SYSTEM AT THE MONTEREY PENINSULA UNIFIED SCHOOL DISTRICT (MPUSD)

Stanley Dobbs-Lieutenant Commander, United States Navy

B.S., University of Memphis, 1991

M.B.A., Florida Institute of Technology, 1999

Master of Science in Operations Research-June 2001

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

This thesis establishes a Forecasting Enrollment Management (FEM) System within the Monterey Peninsula Unified School District (MPUSD). In particular, it examines the effect the forecasting of student enrollment since the untimely departure of the Deputy Superintendent (DepSup) who had performed the function as Chief Enrollment Official for over two decades. The closure of the Fort Ord Army Facility had a significant impact on the accuracy of enrollment projections and inadvertently affected the funding for special program allocations and staffing. The MPUSD has within its control twenty-three schools that service over 12,000 students each year using public funds. Four schools are located within military housing communities and typically service the school-age military dependents residing nearby. Each year's funding is determined by an estimate projected from the previous year's enrollment. The District is required to provide a budget request by April 15th of each school operating year. The school district currently has no computational model adequate for projecting student enrollment; MPUSD uses a working group process to achieve its objective. A model that can more precisely project the number of students in each future year is developed; it can provide a more efficient enrollment management process and provide the necessary checks and balances for the current method. The thesis considers independent community related variables and historical data, and shows that prior-year enrollment figures can forecast future-year enrollment projections with smaller variance than the current working group method.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Enrollment, Enrollment Management, Forecasting, Data Analysis, Data Collection, Process Engineering, Quality Assurance, Continuous Process Improvement

A PARAMETRIC COST MODEL FOR ESTIMATING OPERATING AND SUPPORT COSTS OF U.S. NAVY AIRCRAFT

Mustafa Donmez-First Lieutenant, Turkish Army

B.S., Turkish Military Academy, 1994

Master of Science in Operations Research-December 2000

Advisor: LCDR Timothy P. Anderson, USN, Department of Operations Research

Second Reader: Samuel E. Buttrey, Department of Operations Research

This study provides parametric O&S cost models for future US Navy aircraft acquisition programs based on physical and performance parameters. The proposed parametric cost models provide decisionmakers with a tool for developing rough-order-of-magnitude annual O&S cost estimates for future U.S. Navy aircraft acquisition programs. The historic aircraft cost data was provided by the Naval Center for Cost Analysis (NCCA) in a spreadsheet format and the data were extracted from the Navy Visibility and Maintenance of Operating and Support Cost (VAMOSC) data warehouse. After validating the assumption that the average annual O&S cost for any aircraft type/model/series is constant from year to year, cost estimating relationships are developed. The first model developed is based on multivariate regression. In this case, forward stepwise regression was used to find the model with the best fit. Since the multivariate regression model turns out to be impractical, having more than 30 variables in the equation, a tree-based

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model is presented as an alternative. Additionally, single variable cost estimating relationships are formulated based on the physical and performance parameters length, weight, and thrust.

DoD KEY TECHNOLOGY AREA: Other (Cost Analysis)

KEYWORDS: Cost Estimation, Operating and Support Cost, Aircraft, Regression, Tree Models

USING ON-LINE ANALYTICAL PROCESSING AND DATAMINING TO ESTIMATE EMERGENCY ROOM ACTIVITY IN DOD MEDICAL TREATMENT FACILITIES IN THE TRICARE CENTRAL REGION

**Cary V. Ferguson-Captain, United States Army
B.B.A., University of Notre Dame, 1990**

**Master of Science in Information Technology Management-March 2001
Advisors: Daniel R. Dolk, Information Sciences Academic Group
Samuel E. Buttrey, Department of Operations Research**

On-line Analytical Processing (OLAP) and datamining can greatly enhance the ability of the Military Medical Treatment Facility (MTF) emergency room (ER) manager to improve ER staffing and utilization. MTF ER managers use statistical data analysis to help manage the efficient operation and use of ERs. As the size and complexity of databases increase, traditional statistical analysis becomes limited in the amount and type of information it can extract. OLAP tools enable the analysis of multi-dimensional data, which can give the user access to previously undiscovered information. Data mining has the capability to break large sets of data down into groups by classifications, associations, and clusterings to transform previously meaningless data into useful information.

This research presents a brief overview of the DoD medical system, OLAP, and datamining. OLAP and datamining tools then analyze a data set containing two years of MTF ER data from the TRICARE Central Region. The results of these analyses provide insight on the predictive capabilities, advantages, and disadvantages of applying OLAP and datamining to MTF ER data.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: On-Line Analytical Processing (OLAP), Data Mining, Medical Treatment Facility (MTF), Emergency Room

JAVAMIX: A TACTICAL DECISION AID TO EVALUATE MINEFIELD CLEARANCE PLANS

**José C. Paes Filho-Lieutenant Commander, Brazilian Navy
B.S., Brazilian Naval Academy, 1989**

**Master of Science in Operations Research-June 2001
Advisor: Alan R. Washburn, Department of Operations Research
Second Reader: Gordon H. Bradley, Department of Operations Research**

A Tactical Decision Aid (TDA) for mixed minefield clearance, JAVAMIX, was designed, developed and tested. The TDA uses a Monte Carlo Simulation and it is based on the Monte Carlo option of the TDA MIXER (Washburn, 1995). The JAVAMIX Graphical User Interface (GUI) allows the user to introduce different plans based on the sweep and resource types available and mine types expected. To clear the minefield the user is asked to choose a parameter file and to introduce a plan. Output tables are presented in a DOS window and permit the user to easily visualize if the chosen plan is tactically executable. The design of the system permits future developments such as the implementation of MIXER's other options and the introduction of new parameters.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Tactical Decision Aid for Mine Warfare, Java, Graphical User Interface

THESIS ABSTRACTS

A COST BENEFIT ANALYSIS OF SUPPLYING CONSUMABLE MATERIALS BY READY SUPPLY DEPOT (RSD) VERSUS COMMERCIAL VENDORS

Jose Ernesto B. Gaviola-Lieutenant, Philippine Navy

B.S., Philippine Military Academy, 1991

Master of Science in Management-December 2000

Advisors: Douglas Moses, Department of Systems Management

CDR Kevin J. Maher, USN, Department of Operations Research

The purpose of this study is to examine the current Philippine Fleet (PF) method of supplying consumable materials to Fleet units via a Ready Supply Depot (RSD). The study desires to determine the most cost-effective method of delivering the services currently provided by the RSD in order to fully maximize the use of Fleet resources without sacrificing mission effectiveness. This thesis focuses on the cost the Navy pays to the supplier and all direct and indirect costs of the RSD operation. This study compares the total price of each item inventoried at RSD to a similar item sold by commercial vendors in the Cavite City and Manila area. The difference in price is multiplied by past demand to determine the excess cost to consumers of acquiring consumables from RSD instead of directly from commercial vendors. Additionally, results from RSD consumer surveys are used to assess the service benefits provided by RSD, as seen by its customers. The research results show that the compared items are less expensive to the customer when purchased at RSD. However, it also shows that it is more costly for the government to provide these items via RSD. Furthermore, a customer survey indicates that the RSD customers are not satisfied with the selection, quality, availability, and customer service levels present at the RSD. As a consequence, the recommendation is made to eliminate the Ready Supply Depot (RSD) operation and allow the RSD customers to use commercial vendors for their non-military consumable item needs.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Consumables, Ready Supply Depot, Inventory Management

AN ANALYSIS OF ROTARY WING OPERATIONS IN URBAN COMBAT USING THE JCATS COMBAT MODEL

Harold K. Gibson-Major, United States Marine Corps

B.S., Colorado State University, 1989

Master of Science in Operations Research-September 2001

Advisors: LTC Eugene P. Paulo, USA, Department of Operations Research

CPT Scott T. Crino, USA, U.S. Army TRADOC Analysis Command - Monterey

Second Reader: LtCol Gregory K. Mislick, USMC

The trend of the world's population toward urban areas in the littoral region and increased likelihood of urban conflict has shifted the focus of the military to operations in the urban environment. There is interest within the DoD to evaluate the ability of U.S. forces to operate in the urban environment. In recent years, the Marine Corps has spent considerable time and effort conducting analysis on and development of urban warfare Tactics, Techniques and Procedures (TTPs). There is a need to refine and improve rotary wing operations in this setting.

This thesis modeled and conducted analysis on rotary wing (RW) operations in urban combat using the Joint Conflict and Tactical Simulation (JCATS) combat model. Focus was given to aircraft survivability to evaluate varying tactics and techniques to aid in development of Marine Corps RW TTPs. Thesis objectives were to evaluate rotary wing (RW) survivability in urban combat, determine the major factors impacting on RW survivability, give insight into the development of Marine Corps urban RW TTPs, and to evaluate JCATS as an urban combat modeling tool.

A fractional factorial design was used to vary tactical factors and evaluate their effects. Measures of Effectiveness (MOEs) for evaluation of these effects included Blue RW kills and Blue RW detections.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Urban Conflict, Urban Warfare, Rotary Wing Operations, Urban Combat Modeling Tool

THESIS ABSTRACTS

STATISTICAL ANALYSIS OF NAVAL AVIATION DEPOT REPAIR CYCLE TIME REDUCTION FOR THE F/A-18 C/D AIRCRAFT

Shawn D. Grunzke-Lieutenant Commander, United States Navy
B.S., University of Minnesota, 1989

Master of Science in Operations Research-June 2001

Advisor: Robert A. Koyak, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

Reducing U.S. Navy inventory control problems associated with the F/A-18 C/D aircraft is critical to maintaining squadron readiness while minimizing procurement and repair costs. The Navy's Inventory Control Point has designed its Carcass Express program to ensure that critically short depot level repairables are serviced more quickly. The program was initiated on the S-3 Viking aircraft in 1999. Subsequently, the number of constrained carcasses was reduced by 40 percent, and the average depot repair cycle time was reduced by 12 days. This thesis attempts to quantify the savings that can be realized by instituting the Carcass Express program for the F/A-18 C/D. Data for F/A-18 C/D repairable items that were identified as having insufficient carcasses for repair to meet current demand levels are analyzed. These repairable items have high dollar values and significant backorders severely impacting squadron readiness.

It is shown that the Carcass Express program would provide an additional accrual of inventory over a four-year period for the items studied. The required funding needed to support the deficit between items available from the depot repair cycle and forecast quarterly demands would decrease. The Carcass Express initiative would improve the predictability of the Depot Repair Cycle by reducing repair cycle variability. This ultimately would lead to better inventory management.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Materials, Process, and Structures, Modeling and Simulation

KEYWORDS: Forecasting, Statistics, Repairable, Inventory, Operations

PLANNING U.S. PACIFIC COMMAND WARTIME FUEL DISTRIBUTION

John V. Harmon-Lieutenant Commander, United States Navy
B.S., State University of New York at Albany, 1986

Master of Science in Operations Research-September 2001

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

The Commander-in-Chief, U.S. Pacific Command (USCINCPAC) Joint Petroleum Office (JPO) plans wartime fuel distribution in the U.S. Pacific Command (USPACOM). The USCINCPAC JPO uses manual and spreadsheet based computational methods to assess fuel distribution infrastructures and Operational Plan (OPLAN) supportability. This thesis provides an optimization-based fuel distribution system consisting of linear programming models. Entitled Pacific Petroleum Distribution Model (PPDM), represents the USPACOM fuel distribution infrastructure and accounts for fifty Defense Fuel Support Points (DFSPs). Optimization models provide assessments of distribution capacity and present quantitative rationale to assist JPO in determining distribution requirements while planning and validating wartime fuel support. A series of analyses on notional data demonstrate PPDM's ability to conduct assessments. With OPLAN requirements of 94,000 MBBLs over the 120 day period, PPDM initially identifies significant shortages accumulated before 90 days. Subsequent PPDM analyses show alternatives to optimally schedule additional deliveries and reduce these shortages.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Optimization, Decision Support, Fuel Distribution

THESIS ABSTRACTS

ANALYSIS OF MAINTENANCE RECORDS TO SUPPORT PREDICTION OF MAINTENANCE REQUIREMENTS IN THE GERMAN ARMY

Jens Hartmann-Captain, German Army

Dipl. Ing., Bundeswehr University Munich, 1988

Master of Science in Operations Research-June 2001

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: Joerg Wellbrink, Modeling, Virtual Environment and Simulation Academic Group

Today the German Armed Forces are faced with a broad, varied and graduated range of tasks including missions outside Germany. A major challenge in planning the force structure for missions like the one in Kosovo is to predict the required maintenance capacities. This thesis conducts an exploratory data analysis of maintenance records of the German Army, using the wheeled reconnaissance tank "Luchs" as an example. The question under investigation is whether or not data from the maintenance records can be used to support a future "maintenance prediction tool." It is shown that repairtime distributions extracted from the data can be used to model the repair process in a simulation. The Weibull distribution family, which is commonly used in reliability applications, proved flexible enough to simulate repairtimes and workorder supply times. Implementing these results in a simulation of the repair process will improve the accuracy and quality of the simulation output. In addition, this thesis discusses data quality issues and makes design suggestions for a new maintenance organization software. Data problems can be minimized if the problems identified in this study are aggressively attacked during the design and implementation phases of the new software.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation, Other (Logistics)

KEYWORDS: Maintenance, Repairtime Distribution, Data Quality, German Army

A MULTI-ATTRIBUTE DECISION SUPPORT MODEL FOR 'BEST VALUE' SOURCE SELECTION

Jonathan B. Haynes-Lieutenant, United States Navy

B.S., United States Naval Academy, 1992

Master of Science in Operations Research-June 2001

Advisor: Thomas H. Hoivik, Department of Operations Research

Second Reader: Samuel E. Buttrey, Department of Operations Research

For decades, the federal government has grappled with the issue of how to determine the "best value" offer for services from among competing contractors vice awarding contracts based on lowest bid only. This thesis develops a risk-adjusted cost evaluation decision support model for use in government best value source selection. The thesis presents the Best Value Evaluation Methodology (BVEM), which assists the source selection team throughout the source selection process. BVEM encompasses the fundamentals of "best value" analysis including risk assessments of cost, schedule, technical feasibility, and contractor past performance. BVEM generates a multi-attribute utility measurement (MAUM) score for each proposal based upon the assessed risk. The MAUM score is used to define Triangular and Beta probability distributions for use in Monte Carlo simulations to determine risk-adjusted cost estimates. BVEM also emphasizes the use of upper confidence levels as a better comparison tool for best value than singular point estimates. Additionally, the thesis develops a software implementation of BVEM, called the Cost-Risk Enhanced Source Selection Evaluation Tool (CRESSET). Based on Microsoft Excel and Palisade @RISK software, CRESSET may be used to generate appropriate risk distributions, weighting criteria, quantitative results and visual displays of relative risk for each proposal for use in best value analysis. CRESSET is also useful for preparing more realistic budget estimates.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Contracting)

KEYWORDS: Acquisitions, Contracting, Best Value, Proposal Evaluation, Cost-Risk Analysis, Simulation

THESIS ABSTRACTS

ORGANIZATIONAL CLIMATE AND ITS RELATIONSHIP WITH AVIATION MAINTENANCE SAFETY

Alison E. Hernandez-Lieutenant Commander, United States Navy

B.S., United States Naval Academy, 1986

Master of Science in Operations Research

Advisors: Samuel E. Buttrey, Department of Operations Research

Nita L. Miller, Department of Operations Research

Second Reader: CDR John K. Schmidt, USN, School of Aviation Safety

Naval Aviation is continually looking for ways to reduce its mishap rate. Recognizing a growing concern for issues related to aging aircraft, focus has expanded to include maintenance operations. It is accepted that human error is a causal factor in at least eighty percent of all mishaps, with maintainer, line, or facility-related factors accounting for one out of five major mishaps. One of several actions taken to reduce the mishap rate is the Maintenance Climate Assessment Survey (MCAS). Created to give Naval Aviation unit commanding officers a sense of the maintenance climate of their unit, the MCAS reveals the maintainer's perception of safety climate. Beginning in July 2000, the MCAS administration became available via the Internet. This thesis analyzes the results of the first 2,180 responses recorded via the Internet version of MCAS. Findings include: a) administration of the Internet-based MCAS yields results similar to the paper-and-pencil version; b) differences were detected among the participating units and the Model of Organization Safety Effectiveness components; c) the relationship between MCAS score and Incident Rate, although slightly negative, is indistinguishable from random variation; and d) there was no evidence that demographics bias the results. These findings could be accounted for by the fact that a unit's safety climate typically improves after a mishap. Requiring all units to complete the survey annually would allow tracking over time to uncover trends. One area for further research is investigating the feasibility of adapting the MCAS to afloat and ashore units.

DoD KEY TECHNOLOGY AREA: Other (Naval Aviation)

KEYWORDS: Safety Climate, Human Error, Maintenance

HETEROGENEOUS SALVO MODEL FOR THE NAVY AFTER NEXT

Michael D. Johns-Lieutenant, United States Naval Reserves

B.S., Villanova University, 1994

Master of Science in Operations Research-December 2000

Advisors: Steven E. Pilnick, Department of Operations Research

Wayne P. Hughes, Jr., Department of Operations Research

Second Reader: George W. Conner, Department of Operations Research

The Navy Warfare Development Command has taken the lead in studying needed Capabilities for the Navy After Next. Amongst the ideas they are considering are innovative special purpose littoral warfare platforms as well as alternative relationships between platforms, sensors, weapons, and information. This thesis presents a low-resolution model for analysis of Navy After Next concepts and demonstrates the potential use of the model. Presented is an adaptation of the existing Hughes Salvo Model which had been limited to analysis of engagements between forces composed of identical units, i.e., homogeneous forces. This heterogeneous extension is an analytical device that captures the unique combat characteristics of individual units. The model helps decisionmakers understand salvo warfare of heterogeneous forces by simplifying the complex relationships within and between forces during battle. Using a previous work that tested Hughes' model, the accuracy of this heterogeneous salvo model is examined by comparing results. This thesis further demonstrates the strength of the heterogeneous salvo model through an analysis of a hypothetical campaign scenario and through an examination of alternative tactics.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: Combat Models, Salvo Model, Hughes Salvo Model, Naval Tactics, Campaign Analysis

THESIS ABSTRACTS

AN ANALYSIS ON THE SURVIVABILITY OF LAND ATTACK MISSILES (LAM)

Michael S. Johnston-Lieutenant, United States Navy

B.S., North Carolina State University, 1993

Master of Science in Operations Research-December 2000

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: COL Jeffrey A. Applegate, USA, TRAC Monterey

This thesis develops a process to assist military planners in assessing and evaluating the effectiveness of land attack missiles. The aforementioned process contains the means to address the variety of important issues and concerns that are associated with the employment of such land attack missile systems. The Department of the Navy is proposing a new land attack missile that will be employed by the Destroyer of the 21st Century (DD 21) to assist in performing Naval Surface Fire Support missions for Marines and Army troops operating ashore. This research focuses on using the Extended Air Defense Simulation (EADSIM) to estimate the probability of LAM survival for different variants of land attack missiles against various threats. The analysis concludes that the most survivable cruise missile variants have an altitude of at least 4,000 meters, speed of at least 1,610 knots, and stealthy enough to limit the enemy air defense site detection range to 1% of its maximum range. Survivable ballistic missile variants have a lofted trajectory, speed in the 2,577 knot range, and stealthy enough to limit the enemy air defense site detection range to 10% of its maximum range. The data in this thesis is from unclassified sources, but the process can be applied with classified numerical parameters.

DoD KEY TECHNOLOGY AREA: Air Vehicles, Battlespace Environments, Conventional Weapons, Sensors, Modeling and Simulation

KEYWORDS: Land Attack Missile, Advanced Land Attack Missile, Cruise Missiles, Ballistic Missiles, Missile Survivability

OPTIMIZING POSITIONING OF NAVY WHOLESALE INVENTORY

Cevdet A. Kaplan-Lieutenant Junior Grade, Turkish Navy

B.S., Turkish Naval Academy, 1995

Master of Science in Operations Research-December 2000

Advisor: Gerald G. Brown, Department of Operations Research

Second Reader: CDR Kevin Maher, USN, Department of Operations Research

Naval Inventory Control Point (NAVICP) currently manages more than 210,000 line items to supply 957 customers worldwide. NAVICP positions these items within a distribution network of 22 Defense Depots operated by the Defense Logistics Agency (DLA). NAVICP plans to reduce supply system distribution cost by optimizing their use of this distribution network. This thesis develops a heuristic algorithm that optimally positions line items to serve historical requisitions by Naval units over an 18-month period. Repositioning minimizes distribution costs subject to constraints on customer wait time and depot capacities. This model suggests a distribution scheme for 32,521 unique wholesale items from 22 depots to 126 aggregated customer regions worldwide. The Navy can reduce distribution cost by better strategic positioning of Navy wholesale inventory within the existing distribution network. The Navy can also achieve savings by positioning stocks at just a few locations, rather than at many, and by positioning items together in aggregate product groups, a policy that is widely admired in logistics.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Inventory Positioning, Location Problem, Optimization, Logistics

THESIS ABSTRACTS

MODELING AND SIMULATION IN SUPPORT OF OPERATIONAL TEST AND EVALUATION FOR THE ADVANCED AMPHIBIOUS ASSAULT VEHICLE (AAAV)

Jesse A. Kemp-Captain, United States Marine Corps

B.S., United States Naval Academy, 1995

Master of Science in Operations Research-September 2001

Advisors: Donald P. Gaver, Department of Operations Research

Patricia A. Jacobs, Department of Operations Research

Second Reader: Arnold H. Buss, Department of Operations Research

This thesis documents a simulation model developed to assist in the planning of Operational Test and Evaluation (OT&E) of the Marine Corps' Advanced Amphibious Assault Vehicle (AAAV). The model simulates a platoon of AAAVs in an amphibious assault, using Operational Maneuver From the Sea (OMFTS) techniques, supported by elements of a Marine Expeditionary Unit (MEU) aboard amphibious ships offshore. The emphasis of the model is on suitability issues, specifically operational availability, maintainability, and supportability. In particular the effect of logistical support for one AAAV on the ability of the platoon to complete a mission. The purpose of the simulation is to gain insight into important and highly sensitive factors that, when changed slightly, have large effects on the platoon of AAAV's ability to perform its mission.

The results of the model show that, the assumed form of the distribution of failure times for a single AAAV is the most important aspect of reliability test data. Simply calculating the mean time to failure (MTTF) from data and using an exponential model is inadequate. Even if an observed or estimated MTTF is within an acceptable requirement threshold level, if it is characterized by a high or even moderate number of infant failure times, then the platoon's ability to perform its mission is substantially impeded. Other factors that are of importance are the procedure by which a failed AAAV is rescued and repaired, and the average length of each repair.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human-Systems Interface

KEYWORDS: Advanced Amphibious Assault Vehicle, AAAV, Military Test and Evaluation, Decision Analysis

ENHANCING REAL-TIME TOMAHAWK PREDESIGNATION TO DIAGNOSE CONFLICTS, PRESCRIBE IMPROVEMENTS, AND PLAN MULTIPLE STRIKES

Justin A. Kubu-Lieutenant, United States Navy

B.S., The Citadel, 1995

Master of Science in Operations Research-September 2001

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

Tasking Tomahawk Land Attack Missiles (TLAM) to firing units is complex and time-consuming. This thesis shows how to help the Tomahawk Strike Coordinator (TSC) find efficient, logical and reproducible predesignations (allocations of TLAM tasks to firing units). Previous Naval Postgraduate School work has developed an optimal predesignation and a fast heuristic. However, there may be particularly constrained scenarios in which a complete allocation of tasks to firing units cannot be made. Based upon the cause for the unallocated tasks, the TSC must be able to diagnose and prescribe modifications to unassigned tasks efficiently and logically to arrive at the best allocation possible. This thesis embellishes the fast heuristic to diagnose why a task cannot be allocated and to provide the TSC with recommended modifications to tasks (e.g., change time of launch and/or eliminate redundant task parts). In addition, we improve the fast heuristic to allow sequential allocation of an arbitrary number of sets of tasks. These enhancements offer the TSC new capability to quickly and effectively plan strike warfare.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Optimization, Tomahawk Land Attack Missiles, Tomahawk Strike Coordinator

THESIS ABSTRACTS

A MULTI-COMMODITY NETWORK-BASED HEURISTIC FOR THE SHIP-TO-OBJECTIVE MANEUVER

William B. Lambert-Major, United States Marine Corps

B.A., University of California, Los Angeles, 1989

Master of Science in Operations Research-March 2001

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: Siriphong Lawphongpanich, Department of Operations Research

The Marine Corps is responsible for developing amphibious doctrine and techniques, and conducting amphibious operations. The most critical phase of an amphibious operation is the Ship-to-Objective Maneuver (STOM), the scheduling of which must account for heterogeneous transport aircraft and serials, varied ship-to-shore distances, limited numbers of ship deck spots, and diverse capacities of landing zones ashore. This complex planning is currently done without computer assistance. To expedite the planning and scheduling of the aviation portion of the STOM, this thesis presents the Air Plan Construction Heuristic (APCH). Given a commander's scheme of maneuver and available aircraft, the APCH schedules routes, loads, and departure and arrival times for all aircraft. This heuristic attempts to minimize the time required to deliver all serials, subject to aircraft and ship deck spot availability, and the capacity of helicopter landing zones ashore.

To illustrate the operational planning potential of the APCH, an Air Plan for a MEU scenario is generated, and then compared to a manually-generated schedule. To demonstrate the prospective use of the APCH as an analytical tool, we evaluate the time required to deliver all serials ashore as a function of ship-to-shore distance.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Amphibious Operations, Ship-to-Objective Maneuver, STOM, Multi-commodity Network

STATISTICAL VALIDATION OF TRACK QUALITY NUMBERS FOR JOINT INTEROPERABILITY TESTING OF THEATER AIR AND MISSILE DEFENSE FAMILIES OF SYSTEMS

John W. Leffers-Major, U.S. Army

B.S., United States Military Academy, 1991

Master of Science in Operations Research-June 2001

Advisor: Robert A. Koyak, Department of Operations Research

Second Reader: Patricia A. Jacobs, Department of Operations Research

Joint interoperability is fundamental to the effectiveness of a Theater Air and Missile Defense (TAMD) Family of Systems. Under the Joint Data Network concept, systems compete for reporting responsibility of a possible missile track by issuing track quality numbers related to the covariance matrix of the estimated position and velocity. The system that reports the highest track quality number is assigned reporting responsibility for the track. Verifying that reported track quality numbers are accurate is an integral part of an interoperability test and evaluation program for a TAMD family of systems. In this thesis a framework for measuring the accuracy of track quality numbers, based on reported position and velocity, is described. The framework is applicable to family of system tests consisting of either live missile tracking or modeling and simulation data. Issues that arise in assigning truth objects to tracks are discussed. Measures of performance are proposed based on statistical tests to describe the accuracy of track quality numbers for each system under evaluation in family of systems interoperability testing. Applying the metrics to missile data reveals instances when the reported track quality numbers by TAMD systems are too high.

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation, Command, Control and Communications

KEYWORDS: Tracking, Trajectory Estimation, Track Quality, Interoperability, Test and Evaluation, Theater Air and Missile Defense

THESIS ABSTRACTS

EVALUATION OF COMBAT SERVICE SUPPORT LOGISTICS CONCEPTS FOR SUPPLYING A USMC REGIMENTAL TASK FORCE

**Thomas A. Lenhardt-Captain, United States Marine Corps
B.S., United States Naval Academy, 1994**

Master of Science in Operations Research-September 2001

Advisors: Arnold H. Buss, Department of Operations Research

Gordon H. Bradley, Department of Operations Research

Second Reader: Javier Salmeron, Department of Operations Research

One of the primary responsibilities of a Marine Corps Combat Service Support Element (CSSE) is to provide water, fuel, and ammunition requirements for the primary task forces and other Marine Expeditionary Force (MEF) elements. This thesis evaluates existing and proposed concepts on how to best use the CSSE resources of a Force Service Support Group to transport supplies to Regimental Combat Teams over constrained networks with time constraints. A model was developed that optimizes the use of resources, assets, and network routes. The model first solves a capacitated vehicle routing problem, where a set of customers has to be served by a fleet of vehicles within a certain time. The stochastic aspects of the problem are modeled through the use of a discrete event simulation that uses the results of the optimization model. The optimization model goes beyond the traditional routing problem by accounting for special features such as vehicle capacity for each commodity and cargo incompatibility (e.g. fuel and ammunition). The model includes both optimization of routes and simulation of stochastic elements. As a result, this thesis establishes a basis for future studies involved with modeling new concepts in Combat Service Support.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Marine Corps Combat Service Support Element, Combat Service Support Logistics Concepts, Optimization

A POISSON REGRESSION ANALYSIS OF THE ACADEMIC SETBACK IN NAVAL TRAINING DEADTIME

**Joseph T.C. Li-Lieutenant Commander, Taiwan Navy
B.S., Chinese Naval Academy, 1988**

Master of Science in Management-December 2000

Advisors: Robert Read, Department of Operations Research

Dennis Mar, Department of Systems Management

The dead time in a Naval Training Pipeline is defined as time spent by students enrolled in training doing things other than training. The effect of dead time has been to decrease the utilization of personnel to under 70% in recent times. Four years (1996-1999) of data have been selected for study. The Academic Setbacks for course with CDP identifier 6400 has been chosen for initial work and model building. The methods developed for this case will be applied to Academic Attrition and Instruction Interruption to the extent possible. The exploratory analyses will seek to discover internal temporal patterns of setbacks. The goal is to build methodology for identifying sets of time intervals that exhibit the larger setback and attrition rates.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: Poisson Regression, Training Deadtime, Maximum Likelihood

THESIS ABSTRACTS

RELIABILITY AND LIFE DATA ANALYSIS FOR AN/AAS-44(V) FORWARD LOOKING INFRARED (FLIR) SYSTEM TO FORECAST H-60 OPERATIONAL AVAILABILITY

Glenn J. Lintz-Lieutenant Commander, United States Navy

B.S.B.A., Shippensburg University, 1987

Master of Science in Operations Research-September 2001

Advisor: Patricia Jacobs, Department of Operations Research

Second Reader: CDR Kevin Maher, USN, Department of Operations Research

The AN/AAS-44(V) Forward Looking Infrared (FLIR) System used on the Navy's H-60 Helicopter is taking on an increasing role in helicopter operations and is an important element in the Armed Helicopter design concept. Since its initial acquisition in 1997, the FLIR has been unable to achieve pre-acquisition reliability requirements. Coupled with the high cost of FLIR components, the short times to failure of the FLIR impact Operational Availability (Ao) and cause funding for spares to exceed budgeted levels.

The ability to properly estimate system behavior provides the foundation to adequately fund the level of spares necessary to achieve a level of Ao and to assess the improved system reliability that would result from a system redesign. Two models are developed. The first model assumes the times between failures are independent identically distributed exponential for each unit with different means for individual units. The second model assumes that the times between failure are independent identically distributed and uses the empirical distribution. Both models are simulated. Simulation results are used to estimate the reliability improvement that a proposed system redesign will have. Simulation results also are used to estimate Ao as a function of the number of spares for a carrier battle group. Comparison of simulation results to the Navy's inventory model suggests that current allowance levels are not adequate to achieve mandated Ao goals.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures, Modeling and Simulation

KEYWORDS: Pre-Acquisition Reliability Requirements, H-60 Helicopter, Spares

AN ARMY RESERVE MANPOWER PLANNING MODEL

Ward E. Litzenberg-Major, United States Army Reserve

B.S., Pennsylvania State University, 1985

M.S., Central Michigan University, 1997

Master of Science in Operations Research-June 2001

Advisor: Siriphong Lawphongpanich, Department of Operations Research

Second Reader: LTC Eugene P. Paulo, USA, Department of Operations Research

Because of the expected shortages in its Active Guard and Reserve (AGR) program, the Army Reserve is considering two manpower policy changes. One is the use of Position Vacancy Promotions (PVP) and the other is to allow more officers to serve beyond 20 years of Active Federal Service (AFS). To evaluate the impact of these policy changes, either individually or in combination, on alleviating the shortages, this thesis develops the Army Reserve Manpower Planning model (ARMP). ARMP is an optimization model that determines the annual numbers of accessions, promotions, and separations that best meet the authorized inventory targets. Results from ARMP suggests that a combination of extension of the AFS requirement and allowing PVP can nearly eliminate the shortage in the near future if implemented immediately. ARMP is also useful for managing the AGR officer force.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Modeling and Simulation

KEYWORDS: Manpower Planning, Personnel, Optimization, Army Reserve, Active Guard and Reserve

THESIS ABSTRACTS

COST-ATTRIBUTE ANALYSIS OF RESTRUCTURING H-60R/S FLEET REPLACEMENT SQUADRONS

**Julia M. Lopez-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993**

Master of Science in Operations Research-December 2000

Advisor: LCDR Timothy P. Anderson, USN, Department of Operations Research

Second Reader: Richard E. Rosenthal, Department of Operations Research

The U.S. Navy helicopter community will soon experience an unprecedented transformation; one that will see a massive shift in the identity of the community and in its fleet operations. In accordance with the Helicopter Master Plan (HMP), two new airframes, the SH-60R and CH-60S, will replace the existing helicopter inventory. This thesis develops the optimal way to structure the Fleet Replacement Squadrons (FRSs), specifying the location of the various FRSs and other training necessities. Four organizational options for restructuring the FRSs are considered: two separate airframe specific FRSs per coast, one combined FRS per coast, one FRS per airframe, and one single site combined FRS. Two different training plans are considered with each option. These training plans will consider whether or not to consolidate those portions of the syllabus common to both airframes. Training, maintenance, and support cost data are determined through the use of VAMOSC data and historical annual training requirements. A thorough attribute analysis of the different alternatives is performed. Using standard economic analysis techniques, multi-attribute decision theory is applied to enable a commander to choose the best option for FRS restructuring. When cost attributes are varied, the best alternative is to have two separate FRSs in NAS North Island, and two separate FRSs in NAS Jacksonville/Mayport.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Manpower, Personnel, and Training

KEYWORDS: Helicopter Master Plan, CH-60S, SH-60R, Cost-Benefit Analysis, Flight Training, Additive Weighting and Scaling Model

AN ANALYSIS OF THE INFLUENCE OF SIGNALS INTELLIGENCE THROUGH WARGAMING

**Charles W. McCaffrey-Lieutenant, United States Navy
B.S., Georgia Institute of Technology, 1994**

Master of Science in Operations Research-December 2000

Advisor: Wayne P. Hughes, Department of Operations Research

Second Reader: Gordon H. Bradley, Department of Operations Research

Signals intelligence (SIGINT), information derived from the monitoring, interception, decryption and evaluation of an adversary's electronic communications, has long been viewed as a significant factor in modern warfare. However, relatively little research has been conducted to quantify the influence of SIGINT in war. The purpose of this thesis is to investigate and quantify the influence of SIGINT in warfare by developing an interactive wargame based on the McCue simulation of the U-boat War in the Atlantic. The research comprises two phases. Phase one consists of constructing an interactive wargame version of McCue's simulation. In the wargame, a human player directs convoys across a chessboard representation of the North Atlantic while the computer controls the movement of the U-boats and tabulates the number of U-boat attack-days. Phase one tests how well the wargame models reality using historical data. The second phase of research consists of experimenting within the wargame to explore the effects of varying levels of SIGINT. Each iteration of the wargame, reflecting one of four possible SIGINT conditions, is repeated to derive statistics about the influence of signals intelligence. The results show about a twenty-five percent net change in the number of attack-days for the side utilizing SIGINT.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Java, Modeling and Simulation, Signals Intelligence (SIGINT), Wargaming

THESIS ABSTRACTS

SCHEDULING AND DISTRIBUTING INTRA-THEATRE WARTIME POL REQUIREMENTS

Joseph D. Noble-Lieutenant Commander, United States Navy

B.S., United States Naval Academy, 1989

Master of Science in Operations Research-December 2000

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: David A. Schrady, Department of Operations Research

The Commander-in-Chief, United States Pacific Command (USCINCPAC) Joint Petroleum Office (JPO) oversees the storage and distribution of all petroleum products in the Pacific Theater. JPO planners use the decision support system described in this thesis to help determine if intra-theater wartime petroleum requirements can be satisfied for simulated or operational scenarios. Prior to the work presented in this thesis, JPO performed such analyses manually. The system uses optimization models to produce delivery plans and dispatch schedules for daily shipments of three fuel types via five different transportation modes (pipelines, tankers, barges, railcars, and trucks) amongst fifteen Defense Fuel Support Points (DFSPs). The system uses a spreadsheet interface to import data and to report results, such as fuel inventories and shortages across the distribution network, in tabular and graphical form. Dispatch schedules produced by the system provide detailed schedules for individual transportation assets and test the capacity assumptions employed in the delivery planning model. The USCINCPAC JPO used this system during two recent exercises, simulating wartime operating conditions and environment at the command level; for both exercises the system enabled JPO planners to perform rapid assessments of intra-theater fuel distribution capabilities and quickly validate the feasibility of intra-theater fuel distribution alternatives.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Petroleum Distribution Planning, Linear Programming, Integer Programming, Optimization

FUNDING SITE CLEANUP AT CLOSING ARMY INSTALLATIONS: AN INTEGER LINEAR PROGRAMMING APPROACH

Samettin Oremis-First Lieutenant, Turkish Army

B.S., Turkish Army Academy, 1993

Master of Science in Operations Research-December 2000

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Richard E. Rosenthal, Department of Operations Research

Since 1988, the United States Army has closed 112 and has completed or will soon complete realignment of another 27 of its domestic installations. The Army estimates the total cost (between 1988 and 2001) of these closures and realignments to be \$5.3 billion, of which about \$2.3 billion (43%) is associated with environmental cleanup. Beyond 2001, the Army expects to spend an additional \$1.09 billion to complete cleanup and continue restoration. The Army Base Realignment and Closure Office (BRACO) is currently funding environmental cleanup at 649 sites on 39 current and former Army installations. BRACO's environmental restoration budget from 2001 to 2007 to support cleanup at these installations (totaling over \$620 million) is not sufficient to support each installation's requirement for those years. Considering environmental policies and yearly funding requests from 2001 to 2015 for each site, this thesis develops optimization models and a spreadsheet interface to help BRACO allocate its budget. Model results prescribe either funding each site as requested or delaying cleanup by one to five years. Extensive model use helped BRACO analyze alternate yearly budgets, suggest alternate site funding, and determine site funding for 2001 to 2007.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Program, Optimization, Environmental Cleanup, Budget Allocation, DRAC

THESIS ABSTRACTS

ASSESSING THE UTILITY OF AN EVENT-STEP ASMD MODEL BY ANALYSIS OF SURFACE

COMBATANT SHARED SELF-DEFENSE

Chase D. Patrick-Lieutenant, United States Navy

B.A., University of Virginia, 1994

Master of Science in Operations Research-September 2001

Advisor: Wayne P. Hughes, Jr., Department of Operations Research

Second Reader: Arnold A. Buss, Department of Operations Research

Anti-ship cruise missiles (ASCMs) are increasing in quantity, capability, and availability throughout the world, posing a significant threat to United States naval forces operating in littoral waters. The improving performance and growing availability of ASCMs makes a persuasive argument for the U.S. Navy to aggressively expand surface combatant defense systems, and perform periodic reviews of existing defensive tactics to ensure effective employment of new combat systems. To guide decision makers in both of these areas, simulation and modeling tools are frequently applied. This thesis assesses an event-step Anti-Ship Missile Defense (ASMD) model through the evaluation of two new hardkill weapon systems, the evolved Seasparrow Missile (ESSM) and an improved Rolling Airframe Missile (RAM). The performance of both systems is evaluated within the context of a single-ship and a multi-ship formation responding to ASCM attacks. The goal of this thesis is threefold, namely to assess the effectiveness of additional anti-ship missile defense systems and identify any tactical insights derived from the modeling results of the multi-ship formation. Following these employments of the model, an evaluation is made regarding the use of the ASMD model as a tool for the tactical commander.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Event-Step ASMO Model, Anti-Ship Cruise Missiles, Surface Combatant Defense Systems

DEVELOPING A PROCESS FOR THE DERIVATION OF THE PROBABILITY OF NEGATION FOR THEATER BALLISTIC MISSILE DEFENSE

Mary A. Ponce-Lieutenant, United States Navy

B.S., University of Detroit, 1990

Master of Science in Operations Research-September 2001

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Wayne J. Pavalko, John Hopkins University-Applied Physics Laboratory

Currently there is some ambiguity about the probability of negation in the current literature of Theater Ballistic Missile Defense. The current literature specifies a probability of negation in defense of either a critical asset or a defended area. What needs to be determined is the probability of negation required per target to ensure that the point target or area is properly defended against a raid. This thesis develops a process to determine the probability of negation per target for Theater Ballistic Missile Defense. The aforementioned process led to the creation of a simple but useful tool implemented in Microsoft Excel. The tool allows for a variety of inputs to include multiple layers, varying levels of confidence, varying probabilities of engagement support, and a variable number of shots per salvo per layer. It is available at <http://web.nps.navy.mil/~buttrey/Software>.

DoD KEY TECHNOLOGY AREAS: Materials, Processes and Structures

KEYWORDS: Probability of Negation, Targeting, Negation per Target, Theater Ballistic Missile Defense

THESIS ABSTRACTS

STOCHASTIC SIMULATION OF A COMMANDER'S DECISION CYCLE (SSIM CODE)

Sergio Posadas-Major, United States Marine Corps

B.S., University of Texas at Austin, 1988

Master of Science in Operations Research-June 2001

Advisors: LTC Eugene P. Paulo, USA, Department of Operations Research

Allen S. Olson, White Sands Missile Range

Second Reader: Tom W. Lucas, Department of Operations Research

This thesis develops a stochastic representation of a tactical commander's decision cycle and applies the model within the high-resolution combat simulation: Combined Arms Analysis Tool for the 21st Century (Combat XXI). Combat XXI is a Joint Army-Marine Corps effort to replace the Combined Arms and Support Evaluation Model (CASTFOREM)-a legacy combat simulation. Combat XXI is a non-interactive, high-resolution, analytical combat simulation focused on tactical combat. Combat XXI is being developed by the U.S. Army TRADOC Analysis Center-White Sands Missile Range (TRAC-WSMR) and the Marine Corps Combat Development Command (MCCDC). Combat XXI models land and amphibious warfare for applications in the research, development and acquisition, and the advanced concepts requirements domains. Stochastic decision-making enhances Command and Control (C2) decision processes in Combat XXI. The stochastic simulation of a commander's decision cycle (SSIM CODE) addresses variability in decision-making due to uncertainty, chance and the commander's attributes. A Bayesian Network representation of a conditional probability model for a commander's decision cycle is implemented in SSIM CODE. This thesis develops, applies and evaluates the effectiveness of SSIM CODE.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Command, Control and Communications, Battlespace Environments

KEYWORDS: Combat Models, Simulation, Decision-Making, Decision Cycle

A COMPREHENSIVE STATISTICAL ANALYSIS OF SUBSTANCE ABUSE PATTERNS AND TRENDS WITHIN THE UNITED STATES ARMY

Kevin P. Romano-Captain, United States Army

B.S., University of Utah, 1992

Master of Science in Applied Mathematics-June 2001

Advisor: Toke Jayachandran, Department of Mathematics

Second Reader: Lyn R. Whitaker, Department of Operations Research

The United States Army's Center for Substance Abuse Programs relies on a broad based approach to combat substance abuse. Certain factors, however, have been associated with a soldier's involvement with substance abuse. They include age, race, gender, military occupation specialty, and rank.

A statistical analysis of recent drug and alcohol use/abuse patterns would permit the Army to target services and programs toward those most at risk for developing substance abuse related problems. Additionally, a model that could profile the typical enrollee into the Army's Substance Abuse Program, ASAP, would be a valuable predictive mechanism for future abuse trends within the Army.

This study supports the United States Army's Center for Substance Abuse Programs' efforts to improve the identification of those most at risk for substance abuse. This study provides a detailed statistical analysis on current substance abuse patterns within the United States Army and civilian society, and presents a mathematical model of ASAP enrollments.

DoD KEY TECHNOLOGY AREAS: Biomedical, Manpower, Personnel, and Training

KEYWORDS: Substance Abuse, Alcoholism, Drug Abuse, DUI, DWI, United States Army, Cluster Analysis, Time Series

THESIS ABSTRACTS

ANALYSIS, DESIGN, IMPLEMENTATION AND EVALUATION OF GRAPHICAL DESIGN TOOL TO DEVELOP DISCRETE EVENT SIMULATION MODELS USING EVENT GRAPHS AND SIMKIT

Angel San Jose-Lieutenant Commander, Spanish Navy

B.S., Spanish Naval Academy, 1986

Master of Science in Operations Research-September 2001

Advisors: Arnold Buss, Department of Operations Research

Nita Miller, Department of Operations Research

Second Reader: Gordon Bradley, Department of Operations Research

Discrete Event Simulation (DES) is one of the most widely used methodologies for Operations Research (OR) modeling and analysis. However, designing and implementing DES can be a time-consuming and error-prone task. This thesis designed, implemented and evaluated a tool, the Event Graph Graphical Design Tool (EGGDT), to help OR analysts in the design, implementation, and maintenance of DES reducing the development and debugging times.

The Unified Modeling Language was used to document the development of the EGGDT, which was programmed in Java using J2D and Swing. Human Factors techniques were employed to help in the design process and to evaluate the final prototype of the EGGDT.

During the design process, two formative experiments were performed to evaluate the Graphical User Interface design decisions. A final summative experiment was done to test if the potential users consider the tool a useful means to develop OR simulations. Participants of the experiments agreed that tools like the EGGDT are an essential instrument when developing simulations.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Discrete Event Simulation, Event Graph Graphical Design Tool, Graphical Design Tool

CASE STUDY IN MODELING AND SIMULATION VALIDATION METHODOLOGY

Scott D. Simpkins-Captain, United States Army

B.S., West Virginia University-Institute of Technology, 1990

Master of Science in Operations Research-June 2001

Advisor: Lyn R. Whitaker, Department of Operations Research

Second Reader: LTC Eugene P. Paulo, USA, Department of Operations Research

The military develops and uses simulations to analyze nearly every aspect of defense. How accurate are these simulations and to what extent do they produce dependable results? This thesis explores practical validation techniques from the bottom-up in the form of a case study. The platform used is the theater ballistic missile defense aspects of the new simulation Wargame 2000. This research will be particularly useful when combined with further case studies to provide a global perspective to validating large-scale military models and simulations. Wargame 2000 is compared to a baseline existing model, EADSIM.

The focus here is not to validate or invalidate Wargame 2000 but to develop real, usable tools to compare a simulation's results against baseline results. This work focuses on measures of effectiveness characteristic of missile defense. Data collection includes defense battery search, engagement and intercept times for a variety of threats but does not include tracking information. Results from each model are compared using both graphical methods and inferential statistics. Insight is provided into developmental and data production issues which can make the validation process more effective and meaningful.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Validation, Simulation Validation, VV&A, Model-Test-Model, Wargame 2000, EADSIM, Theater Ballistic Missile Defense

THESIS ABSTRACTS

ANALYSIS OF ROUGH SURFACE LIGHTING BEHAVIORS WITH OPEN GL

**Christopher P. Slattery-Lieutenant, United States Navy
B.S., United States Naval Academy, 1994**

Master of Science in Modeling, Virtual Environments, and Simulation-September 2001

**Advisor: Wolfgang Baer, Department of Computer Science
Second Reader: Samuel E. Buttrey, Department of Operations Research**

In the physical world, humans gather valuable information about objects through their sight. Information on shape, feel and composition are seen long before the object is touched. This information is generated by light reflecting off the surface of objects. Despite the advancement of computer graphics due to increased hardware rendering capacity, the fundamental equations, which draw three-dimensional scenes, lack the ability to truly model realistic objects. Whether it is smooth like highly polished metal or rough like the shag of a carpet, it is the reflection of light that tells humans what a surface feels like. The attempt taken in this thesis to implicitly model the roughness of textured surfaces through examination of an explicit model rendered with the OpenGL lighting equation. This approach has the potential to successfully increase the realism of computer graphics without increasing polygon count required for explicit surface generation. Through simulation of an explicitly constructed rough surface followed by the analysis of the behavior of its reflected light, the initial behaviors of textured surface reflections are identified. While these behaviors are not enough to create corrections to the OpenGL lighting equation, they lay the foundation for further development.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human-Systems Interface

KEYWORDS: Open GL, Lighting Behaviors

EFFECTIVENESS OF NAVAL SURFACE FIRE SUPPORT TO THE ARMY BRIGADE

COMMANDER IN A LITTORAL CAMPAIGN

**Juan K. Ulloa-Major, United States Army
B.S., United States Military Academy, 1990**

Master of Science in Operations Research-June 2001

**Advisor: LTC Eugene P. Paulo, USA, Department of Operations Research
Second Reader: Arnold H. Buss, Department of Operations Research**

Since the end of the Cold War, the Army has been engaged in an unprecedented number of joint contingency operations that run the gamut from humanitarian efforts in Cuba and Haiti to peace-enforcing and peace-keeping in Bosnia to full scale war in Southwest Asia. These operations, the result of an increasingly complex international security environment, hint at future missions involving American forces aimed at protecting U.S. interests worldwide.

To engage and defeat future threats to our national security, the Army must transform itself into a more strategically responsive, lethal force. The Army is faced with the challenge of lightening the force while simultaneously increasing its survivability and lethality. Reach-back technologies from sea, air, and space can provide Army units with added lethality without encumbering them further.

This thesis analyzes the ability of the Army to effectively utilize Naval Surface Fire Support (NSFS) to provide indirect fire in support of brigade-sized units. The Fire Support Simulation Tool (FSST) takes the capabilities and limitations of weapon systems being studied and simulates their employment in the context of a well-defined scenario for analysis. The output from the simulation provides the input for the analysis of NSFS.

By comparing the utility of several well-constructed courses of action, the FSST can help decision-makers determine the effectiveness of NSFS within the context of the scenario being considered. The results of this analysis determined that although a myriad of issues such as training, mistrust, and synchronization must be addressed to make reach-back fires successful, there is strong quantitative and analytical evidence to support the effectiveness of NSFS to an Army Brigade commander engaged in a littoral campaign.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Computing and Software, Conventional Weapons, Modeling and Simulation

KEYWORDS: NSFS, Simulation, Java, FCS, IBCT, Artillery, DD21, DD-21, Paladin, Crusader

REDUCING NON-MONOTONICITIES IN COMBAT MODELS

William C. Vinyard-Major, United States Marine Corps

B.A., University of Colorado, Boulder, 1988

Master of Science in Operations Research-September 2001

Advisors: Thomas W. Lucas, Department of Operations Research

Carlos F. Borges, Department of Mathematics

Paul J. Sanchez, Department of Operations Research

Non-monotonic behavior in combat models is an important topic to those using the output of such models as a basis for decision making. These decisions can be complicated by non-monotonic behavior in the combat models. This paper examines the Dewar model which exhibits non-monotonic behavior caused by the chaos inherent in its structure. Previous papers have examined only small subsets of this 18 dimensional combat model. The combinatorial possibilities of main effects and interactions among the 18 dimensions are too great to examine en masse. Consequently, there are three goals. First, systematically explore the Dewar model for additional non-monotonic behavior. Second, determine the effect of stochastic modeling on the non-monotonic behavior of the Dewar model response surface. Third, develop a method for measuring non-monotonicity in the response surface generated by the model. Latin Hypercube Sampling discovers non-monotonicity across broad regions of the model's phase space, and in multiple measures of effectiveness. Stochastic perturbation of model parameters has a dramatic effect on the non-monotonicity of the response surface. Stochastic perturbation can both reduce and exacerbate the non-monotonic behavior of the response surface. If done properly, stochastic modeling can significantly improve the interpretability of the response surface.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Combat Models, Non-Monotonic Behavior, Stochastic Modeling

SCHEDULING THE RECRUITING AND MOS TRAINING OF ENLISTED MARINES

Darrin L. Whaley-Major, United States Marine Corps

B.S., United States Naval Academy, 1989

Master of Science in Operations Research-September 2001

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Javier Salmeron, Department of Operations Research

Non-infantry enlisted Marines progress through Recruit Training, basic infantry training at Marine Combat Training (MCT), and Military Occupational Specialty (MOS) training before finally reporting to their first unit for duty. These Marines are the focus of this thesis. In fiscal year 1998, new recruits spent over 2,700 Marine-years (wait time) in an unproductive status while waiting on their next training schools to convene. Marine Corps manpower planners believe this level of wait time is unacceptable. This thesis develops two integer linear programs to plan recruiting and MOS school seat scheduling with the primary objective to minimize the time non-infantry enlisted Marines wait for MOS training. The first model, the Long-term Recruiting and MOS School Scheduler (LRAMS) plans both recruiting and MOS training to help MOS training schools' develop their training schedules two years prior to execution. The second model, the Short-term Adjusted Recruiting Model (STAR) is used after the MOS training school schedules are published to develop a coordinated recruiting schedule. Results indicate that wait time can be reduced significantly. For fiscal year 2001, LRAMS results provide a wait time of only 160 Marine-years.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Manpower, Personnel and Training

KEYWORDS: Integer Optimization, Scheduling, Resource Constrained Problems

THE BOOST PROGRAM AND ITS EFFECT ON RETENTION AND PERFORMANCE

Tracy D. Whiteley-Lieutenant Commander, United States Navy

B.S., Drexel University, 1990

Master of Science in Operations Research-December 2000

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

This thesis is an analysis to determine if fleet input (Track I) compared with civilian input (Track II) personnel into the Broadened Opportunity for Officer Selection and Training (BOOST) program is related to the retention and performance of a Navy commissioned officer. The data focuses on BOOST classes, 1981-1992, to measure fleet performance and retention. Prior-enlisted officer (Track I) BOOST graduates obtain a subspecialty, receive graduate education, and enter the Lieutenant Commander promotion board at statistically significant higher rates than their civilian (Track II) counterparts. It is hypothesized that candidates with a "prior service" background have more knowledge, commitment and overall understanding of the military that will help them succeed as officers.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel and Training

KEYWORDS: BOOST, Officer Programs, Prior Service, Retention

AN IMPROVED HEURISTIC FOR TOMAHAWK LAND-ATTACK PREDESIGNATION, ENHANCED TO ACCOMMODATE MANUAL PLANNING, AND VALIDATED

WITH FLEET EXERCISE DATA

Paul H. Wingart-Lieutenant, United States Navy

B.S., United States Naval Academy, 1995

Master of Science in Operations Research-September 2001

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

The Tomahawk Land-Attack Missile (TLAM) has become the weapon of choice for strategic and tactical land-attack warfare. Tomahawk provides long-range, reliable, unmanned land-attack capability with pinpoint accuracy. Strike planning is the process by which Tomahawks are assigned to firing units for target prosecution. Currently, the Tomahawk Strike Coordinator (TSC) performs strike planning by hand. In order to improve strike planning, a fast heuristic has been developed to allocate TLAM tasks-the target to be attacked and the time period in which the missile must be fired-to firing units in multiple battle groups and launch areas over successive time periods. Until now, the heuristic with just 12 simulated scenarios was tested. To determine the heuristic's performance vis-à-vis current manual strike planning, heuristic solutions to TSC allocations from two U.S. Third Fleet exercises-TEXAS THUNDER 00-6 and RIMPAC 00-3 are compared. The heuristic produces a more efficient allocation than the TSC for every one of 13 exercise salvos. The heuristic to accommodate manual planning is augmented, with two computer-assisted alternatives - task-to-firing unit and firing unit-to-task - that help the TSC discover and address subtle details that influence mission success, and apply expert human judgment regarding practical considerations.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Strike Planning, Tomahawk Land-Attack Missile, Tomahawk Strike Coordinator

THESIS ABSTRACTS

FINDING THE IMPORTANT FACTORS IN BATTLE OUTCOMES: A STATISTICAL EXPLORATION OF DATA FROM MAJOR BATTLES

Faruk Yigit-First Lieutenant, Turkish Army

B.S., Turkish Army Academy, 1995

Master of Science in Operations Research-December 2000

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: Eugene Paulo, Department of Operations Research

This study explores important factors in battle outcomes through a statistical analysis of data from major historical battles. The data set of CDB90FT has been made available and documented by the Center for Army Analysis (CAA). The quality of the historical data is good. There are 660 battles listed in the data set containing over 140 numerical features for each battle. The earliest battle in the data set is the Netherlands' War of Independence in 1600, while the last one is from the Israel-Lebanon War in 1982. The data set contains many interesting facts on the battles including the initial strengths, the total strengths, the number of casualties, the lengths of the front lines, terrain features, command capability of leaders, weather conditions, etc. The approach is to use the data set as the basis for an objective and scientific comprehensive analysis, seeking patterns, trends, and relationships in combat. After making campaign-wise grouping and analysis, it is found that the Force Ratio is a valid estimator of the battle outcome. In addition, the Casualty Rate has declined steadily over the past four centuries while Dispersion has increased.

DoD KEY TECHNOLOGY AREA: Other (History)

KEYWORDS: Dispersion, Daily Casualty Rate, Force Ratio

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